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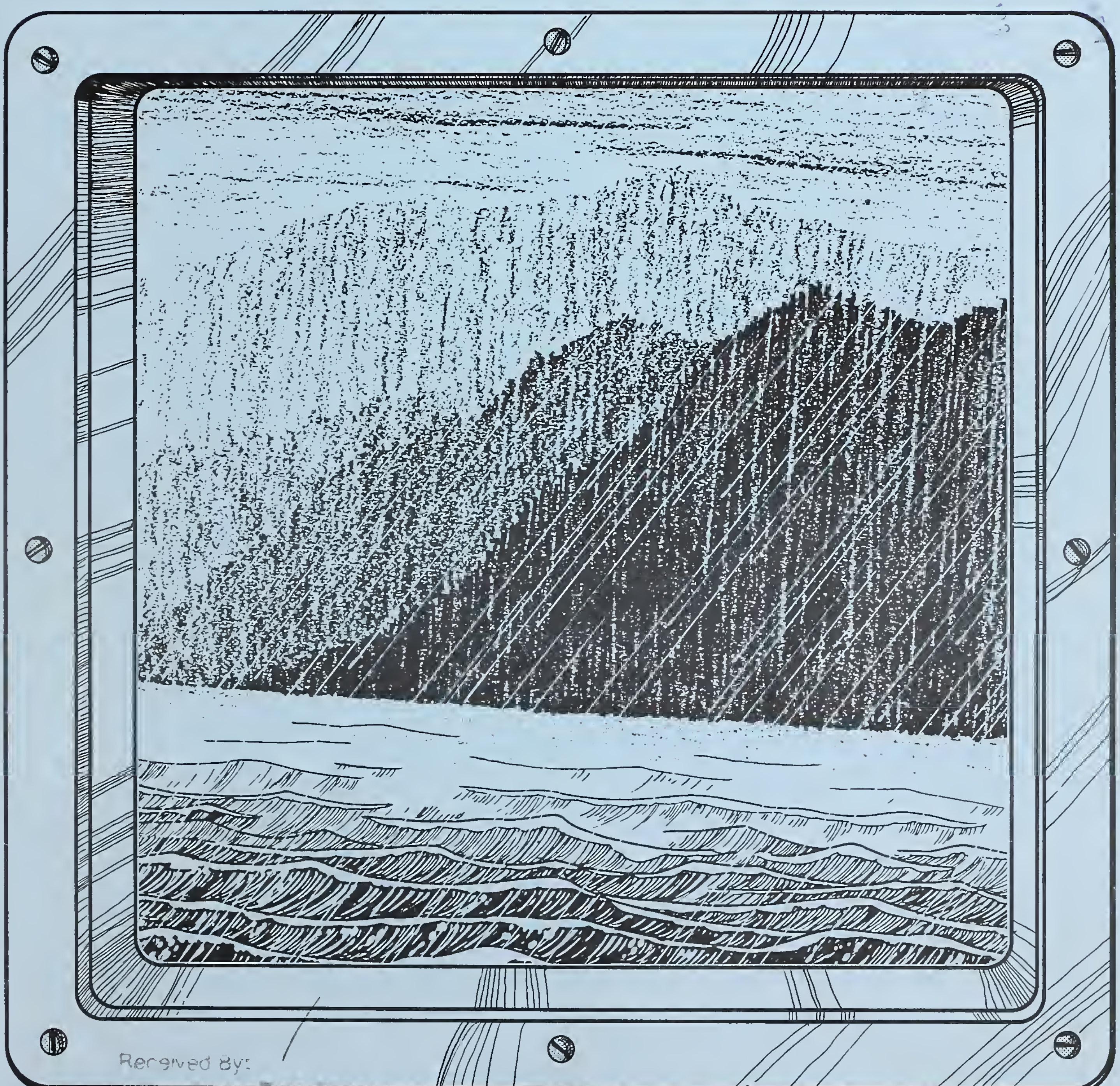
Proceedings of

Watershed '91

A Conference on the Stewardship of Soil, Air, and Water Resources

Juneau, Alaska
April 16 - 17, 1991



PROCEEDINGS OF WATERSHED '91

Soil, Air, and Water Stewardship Conference

Juneau, Alaska
April 16 & 17, 1991

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Forward

Max Copenhagen

Watershed '91 was the second biannual conference on stewardship of forest lands in the Alaska Region. In April 1991, we met in Juneau, Alaska for two days focusing on a theme of Riparian Ecosystems. The program emphasized New Perspectives (Ecosystem Management), Fish Habitat / Landform Interactions and Monitoring. Two panel discussions and several posters were also presented.

The intent of this conference was to provide an opportunity for approximately 78 scientists and resource managers to meet, express, and discuss recent research, ideas, and opinions. These Proceedings are the tangible expression of what was presented there.

The purpose of these Proceedings is to provide 1) those who could not attend with a record of the information presented, and 2) participants with an opportunity to publish their work. All final papers provided by the authors are included, otherwise an abstract is used. It was our stated intent to publish all reviewed papers presented at the conference.

Max Copenhagen is Watershed Group Leader for the Alaska Region of the U.S. Forest Service, Juneau Alaska.

We recognize that diverse viewpoints can prompt constructive dialogue. Each paper was reviewed by at least two peers. Comments and recommendations for revision were provided to the authors. The degree to which the paper was revised was left to the professional judgement of the author. The final papers, therefore, are the viewpoints of the authors and do not necessarily represent the opinion or policies of the USDA, Forest Service.

This conference was a challenging endeavor. Participant critiques indicated a desire for more private sector speakers. The scientific credibility of future events may benefit from co-sponsorship by another agency, university or non-government entity. Collaboration between Watershed and Biologist staff on venue and program is also desirable in the future.

Thank you for your participation and interest in **Watershed '91**. As our land management philosophy evolves and new science and information is available, we will periodically continue this tradition. In the meantime, let's continue to implement the principles of wise use and adaptive management and demonstrate good stewardship of land and ecosystems in the Alaska Region.

Contents

Welcome

Stewardship First, Our Vision of Watershed Management in the Alaska Region

Robert W. Williams

First, I want to thank you all for coming and to acknowledge our Canadian friends and others who have come up from the Pacific Northwest. Many resource issues are global and the Forest Service wants to be an international leader in resource protection and management. The recent decision to create a new Deputy Chief for International Forestry is an example of this emphasis.

WATERSHED MANAGEMENT IS AN IMPORTANT PART OF THE JOB

Our basic authority for Watershed Management goes back to the 1897 Organic Act. Many National Forests were acquired under the Weeks Act specifically to protect watershed values.

Relatively recent legislation, such as the Clean Water Act, and the Clean Air Act, give us additional authority and direction to protect these basic resources.

Watershed Management continues to be a critical part of the overall Forest Service mission. Soil, Water, and Air are Resources, not constraints.

Our "stewardship" programs for protection of Soil, Water, and Air resources are the way we "care for the land". "Stewardship" means conservation, maintenance, and wise use of what we have.

CONCERNS

We have vast and resilient renewable resources in Alaska. We also have vast wetland and riparian areas, most of which are in excellent condition. Most of our water is high quality, and we want to keep it that way. [We have water to spare, if we could only get it to California].

Although aquatic habitat is the main "beneficial use" of waters flowing on the National Forests in Alaska, concerns for water quality are not limited to fisheries.

As "environmentalists", we who manage the land are concerned about forest "health" and the quality of our water, air, and soil because these are the basic resource upon which long-term soil and site productivity is based.

We want to continue to have abundant and healthy wetland and riparian areas. Health means resiliency and a natural potential to recover and heal after disturbance.

Although forest use is not possible without some adverse effects, we are concerned that long-term site productivity be maintained. Standards and Guidelines for soil in the Forest Plans will help assure this.

We are also concerned about the protection and use of Wetlands in Alaska. We need to maintain appropriate wetland function and value. A road across a forested peatland is fundamentally different from a road in a riparian area or near an estuary. We need to work together to assure that reasonable economic development continues in Alaska without degrading these important resources.

NEW PERSPECTIVES

We want to have a proper balance between use and protection of all resources. New Perspectives will help us achieve this balance.

Two New Perspective themes which fit well with Watershed interests are Site-landscape Integration and Adaptive Management.

I encourage the use and marketing of your conceptual skills, such as cumulative watershed effects analysis, to help address questions of scale, such as old growth block size and clearcut patchiness.

The other New Perspective principle I want to encourage you to examine is Adaptive Management. We need to plan well, then do it, and then record it. Let's have a bias for action and learn from our experience as we go.

The Alaska NPS Pollution Control Strategy recently developed under Sec. 319 of the Clean Water Act is a good strategy for implementing water quality protection.

By cooperating on soil and water quality information needs and focusing on clear and essential monitoring questions, we can work together to make this happen.

I expect the quality of basic resources on National Forest lands to be at least as high and essentially "consistent" with soil, water, and air quality on other lands in Alaska. Recent changes in the Coastal Zone Management Act may help to tie CZMA and CWA programs together to help us achieve a more constructive resource management strategy.

I am please that all units now have developed watershed visions and goals. You need to be aggressive about expressing these goals in the context of the FY93 budget.

We have been successful in increasing the Soil, Water, Air budget level both nationally and to the Region. But don't let

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a shortage of FTEs be a barrier to getting work done on the ground. FTEs will not increase much and will always be scarce. Be creative. Seek partnerships. Collaborate and work together with others to achieve our mutual stewardship goals in the most effective way.

Sort out that kind of work that can be done by personal service contracts to free your time for the essential work that must be done by watershed staff.

I encourage you to clarify the essential resource objective without jumping ahead to anticipate what should be limited or controlled. Be specific, but don't prejudge what can be done. Some times you can have your cake and eat it too.

I hope you will hear these presentations today and add a health dose of your own experience to derive the kind of applied science that will help us care for the land in the best practical way.

I encourage you to question the speakers and panel members and be skeptical, but not cynical.

I want you to know that Watershed Management is respected as a neutral interest, not an advocate or fish or logs. You are perceived as being concerned about the overall watershed condition. I hope you will continue to help us provide sound integrated resource management.

Earth day is April 22. Let every day be earth day. Lets work together to make Stewardship Happen.

Keynote Address, Watershed '91 Conference

Working Cooperatively to Implement New Perspectives Strategies on a Landscape Level

George W. Brown, Oregon State University

INTRODUCTION.

It is a genuine pleasure for me to be here at this Watershed '91 Conference and to have the opportunity to address a group of professionals interested in the management of watersheds. It is a rare experience for me these days to once again don the mantel of a forest hydrologist and return to the professional origins I cherish so much.

Mike Barton and Max Copenhagen have asked me to discuss with you tow important topics. The first deals with the watershed aspects of New Perspectives, especially those issues relating to management of resources on a landscape scale and, coincidently, cumulative effects. The second is our experience with interagency cooperation, and obvious need if landscape scale management is to be implemented.

Watershed Management Aspects of New Perspectives

Let's begin with the New Perspectives program. As an academician, it has been an interesting experience to watch the New Perspectives program emerge so rapidly and in the midst of the debate over management and allocation of our region's resources. The politics and personalities involved have been fascinating! I can recall no other forestry program which has moved from concept to implementation on a national scale so swiftly and, in the process, received so much publicity. It has truly been phenomenal.

Regardless of your view about New Perspectives, an important result has been the debate this concept has generated. If done professionally, such debate is healthy and can lead to better resource management decisions that reflect people's needs and values. Indeed, the debate has already moved the discussion from the early New Forestry focus on partial cut silviculture that seems to be focused on the non-game aspects of biodiversity to a discussion of goals and objective sin the broadest sense.

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The focal point in the New Perspectives initiatives, in my opinion, it this broadened view of resource management goals, both in terms of the number of resources considered and the areal extent over which resource management decisions will be implemented and evaluated. Much of the discussion centers on integrating management decisions affecting multiple resources into a cohesive framework that is clearly more than an amalgamation of individual resource management prescriptions. People are also beginning to think of basins as the logical basis for planning unit designation, and not just the first and second order basins we are accustomed to, but fourth and fifth order and larger.

The challenges of actually implementing this kind of management are formidable technically, socially and politically. for example, how do we get people to agree on the goals for integrated forest resource management? With so many advocates for single resources, how can we achieve consensus on outputs?

Yet for those of us who claim to be resource management professionals, New Perspectives is clearly a set of marching orders to get on with something we have told people we can do: manage large tracts of land for a multitude of resources and values, most of which are non-market in character. And if your background is in watershed management or forest hydrology, the idea of basin-level management is one you have heard preached in college classrooms for at least three decades.

So how do we pull this off? It seems to me we must begin by stripping away the rhetoric that surrounds New Perspectives and articulate very clearly, for ourselves and the policy makers and the public, what we know and what we don't know, what we can do, what we think we may be able to do and what e clearly can't with the knowledge now at hand. A favorite historian of mine, Daniel Borstein, once made the point that human progress has, through the ages, been thwarted not so much by ignorance, but by the illusion of knowledge.

Can we really predict the impact of timber harvest and fish or wildlife with enough reliability that allows us to choose between alternative harvest systems or levels? Can we really predict cumulative effects on water quality, much less fish? And how about anadromous fish runs? Can we really sort out the impact of timber harvest from all the factors influencing those fish throughout their life cycle? I suggest that if we held such a conversation, it would help us focus in on the key issues limiting truly multiple use management on a landscape scale. With all the recent political and judicial pressure, I fear we are promising more than we can deliver and we are raising expectations to heights unreasonable.

As an example, let us take the issue of cumulative effects. Conceptually, it seems like a reasonable thing to expect impacts from various activities in a basin to "accumulate" downstream. After all, one of the earliest environmental issues to catch the public's attention was the accumulation of DDT in food chains.

The problem is that for many of the environmental variables we deal with, natural background variability often effectively masks additions caused by human activity. And the transport processes are extremely complex. All of you are familiar with sediment transport dynamics, I'm sure. Our studies in streams of the Oregon Coast Range show that sediment concentrations on any given stream vary as a function of stream discharge, sequence of the storm event within the rainy season, whether the stage was rising or falling, and the disturbance of the stream channel and basin slopes by natural or human factors. Couple these sources of variation with those imposed by soils, geology, and topography differences within large basins and the predictability of the transport process is made even more difficult. In sum, cumulative effects are not a matter of simple addition. Peak flows from upper basins get flattened as they move downstream, chemicals get absorbed and disappear, sediment is deposited, and temperature pulses get diluted.

Yet, courts and the public are convinced that cumulative effects cannot only be predicted and quantified through monitoring programs, but that effects can be mitigated or eliminated by such simple-minded techniques as harvest scheduling. Where did they get that idea? And what have we done to help them better understand the limits of our knowledge to predict and monitor such changes?

I'm sure you've seen harvest scheduling schemes proposed as solutions for all kinds of cumulative effects problems. My first experience was in Montana with some snow melt/harvest area models that got built into forest plans in the early 1970's. There was, it turns out, no validated scientific justification. Currently, there is a proposed forest policy agreement between the Sierra Pacific Industries in California and some environmental groups "to limit the cumulative adverse water quality effects of extensive timber harvests within a watershed" by stipulating that "no more than 15 percent of each ownership within a watershed may be subjected to clearcutting within a 10 year period." And clearcutting is defined as removal of more than 70 percent of the volume. But 100 percent of an ownership can be harvested in a 10 year period if less than 10 percent of the average basal area is removed during this period, or 50 percent of an ownership can be harvested if no more than 50 percent of the basal area is removed. What is the scientific justification for these numbers? What are the ecosystem responses to these prescriptions? What are the costs and benefits of employing such a scheme? Such specificity implies we know.

A portion of this conference deals with monitoring. Have we really thought about how to put in place a monitoring program that is sophisticated enough to detect cumulative effects for the types of nonpoint source pollution we normally deal with that have great natural variation in both time and space? And in basins that are a complex mosaic of geology, vegetation types, and land uses? Oregon is struggling right now with just such a problem.

The Tualatin River begins in the forested slopes of the Coast Range and flows east through farm land and then through a rapidly-growing urban region that serves the urban fringe for Portland. The river has severe problems each summer during the low-flow period when phosphorous from septic tanks and sewage treatment plants cause algae blooms and dissolved oxygen problems. The state water quality authority has chosen to deal with the problem using a Total Maximum Daily Load (TMDL) approach, where each "polluting" user group (agriculture, forestry, urban) has been assigned a maximum daily load based on a set of "loading factors" generated by computer model. A model, I might add, that has not been validated. Once this is done, the responsibility for monitoring compliance falls to the "designated management agency" - the Oregon Department of Forestry for forest operations and forest lands, and the Oregon Department of Agriculture for farming operations and agricultural land. TMDL monitoring does not mean monitoring the application of best management practices required by our Forest Practices Act. Monitoring means water quality monitoring, something the Department of Forestry has never been required to do before.

Now put this into a cumulative effects framework. First, we don't have good mathematical descriptions of the relationship between forest practices and phosphorous production, regardless of the computer model. Second, in a basin with intermingled farms, forest, and rural home use, how do you separate sources? Third, if you get a value that exceeds the assigned limit, what actions do you take? Which operations do you close?

Frankly, phosphorous should not be a problem in the forested tributaries of the Tualatin, especially in summer when runoff is almost entirely base flow. But what if this were a sediment issue? How would we deal with it? What sort of cumulative effect model would we use to assign loading factors to forestry, agriculture, urban development, or highways? Do we have any models that have been scientifically validated?

How many invalidated cumulative effect models do we have driving our forest plans? Yet I would submit that good cumulative effect models are exactly what we need. And I emphasize good. They may never be very precise, but I would argue that models which provide our managers and policy makers with a true sense of variability or relative risk would be very helpful as we try to implement New Perspectives strategies. The real problem with most models, in my opinion, is that their precision is never clearly described so that managers or the public can honestly appraise the accuracy of the results. My definition of a "good" model is one that features full disclosure - a clear specification of assumptions and their validity up front (not buried in Appendix W), functional relationships clearly defined and justified, with a candid appraisal of accuracy (preferably using tests of validity and sensitivity) and breadth of application. For most nonpoint sources of pollution and cumulative effects, we have a long way to go before we meet these criteria.

Once we've identified what we know and what we don't know, we can get on with the process of finding some answers. But this sorting process has several intrinsic values in and of itself. Experience shows that where it is done correctly, it helps people with different viewpoints to sort out fact-based differences from value-based differences and come together around finding answers to key questions. And this establishes some common ground. Daniel Botkin, an internationally known ecologist at the University of California Santa Barbara and author of the book entitled Discordant Harmonies, described such an experience during a recent visit to our campus. Dr. Botkin led a team of eminent scientists as part of a process to resolve a major controversy surrounding water diversion in the Mono Lake Basin in California. The scientists found that a great deal of what was supposedly known about Mono Lake's ecology, geology, and hydrology was, in fact, myth. By clearly articulating what was fact and what was unknown, the team helped adversaries come together behind data collection efforts and focus on the really divisive issues that were usually value-based.

I also believe similar opportunities are available to us in forestry. A prominent environmental leader came to visit me with a suggestion that the universities could play a very helpful role in resolving environmental controversies by acting as a "third party" facilitator that identified facts and knowledge gaps, thus allowing the discussion to focus on differences in values. In his opinion, the endless litigation of natural resource management is leading nowhere. And that is a remarkable conclusion given the success his and other such organizations have enjoyed in the courtrooms. If his attitude reflects a general change in strategy, I believe there is hope that we can eventually resolve our current impasse. The hinge pin in this process, I must remind you, is people like yourselves acting in a avery professional way to help separate known from unknown.

It is imperative that we broaden the circle of conversations in this process of doing a reality check to include our colleagues in the social and behavioral sciences. Traditionally, resource management discussions have involved biologists, some economists, and perhaps a few engineers. But until we involve social scientists, we are unlikely to adequately evaluate human needs or expectations. And that is political suicide.

The next step will be building some strong partnerships between resource and management, between agencies, industries, and interest groups to test on a landscape scale some of our hypotheses about how alternative management strategies perform economically, biologically, and socially. I'll come back to the structuring of such an enterprise later.

The need for such partnerships stems from the nature and magnitude of the job confronting us. If we truly wish to test New Perspectives ideas or hypotheses at a landscape or basin scale, the likelihood of only one landowner or resource management agency being involved is very remote, except maybe in Alaska, where, as you keep reminding us lower-48ers, things are different. But even here, partnerships between researchers and those who manage the resources will be crucial. If we don't build such partnerships, we are likely to lose the opportunity to learn from what we do.

Building Partnerships - The Oregon Experience

There is ample precedent for successful partnerships between research organizations, public resource management agencies, industry, local government, and the public. I wish to describe one such partnership for you. The example I've chosen is the COPE program in Oregon. it is successful and the focus is on multiple resource values.

The Coastal Oregon Productivity Enhancement Program, or COPE, was born out of a need for new information. Oregon's coastal forests are some of the most productive in the world for wood, water, wildlife, and fish. And the conflicts between resource users and managers are legion.

We got people together in the early 1980's and asked them to help identify the key problems that were hindering our ability to manage these forests. It boiled down to two key questions: How can we manage riparian areas to produce an array of timber, fish, wildlife, and water resources? And second, how can we insure reforestation of upper slope sites and achieve wildlife and site productivity objectives under an array of vegetation management constraints? So we began with consensus on the management problems to be addressed. These problems then set the stage for identifying the research needed.

Second, we put in place an advisory council to provide policy advice, general review of progress, and to act as advocates with our congressional delegation and local support groups.

Third, we implemented an organizational structure for doing the work which would had proven its worth in an earlier cooperative research and management venture in southwest Oregon. The key to this organizational structure was building an adaptive or applied research group that also did technology transfer into the organization from the beginning. Our experience in southwest Oregon clearly indicated that such a group provided the necessary liaison between the fundamental scientists and those interested in putting the research to use. They became the local contact for the agencies, industry, county government, the media and the public. They held local workshops, produced a newsletter, established demonstration areas, answered hundreds of phone calls, made "trouble shooting" visits and kept the media up to date on findings. We have built the same type of organization into COPE.

My point is that partnerships have got to be more than memoranda of understanding and annual meetings. They take nurturing, which means lots of good, personal communication, preferable in the woods

Partnerships also require a strong sense of ownership by all parties. It begins with consensus on problem identification. But we also built ownership by including our partners in the design and conduct of workshops, in helping to install and monitor research plots, by sharing practical experiences in our newsletter, in co-authorship of publications, in periodic reviews of progress and, of course, financial support. Ownership insures that research results will be implemented and not just left on the shelf.

Our cooperative effort in southwest Oregon also produced some unexpected benefits for the cooperators. Advisory Council meetings were an opportunity for people to come together on neutral turf to talk about a common problem -- reforestation. That experience led to better working rela5-tionships between people and organizations that had been at odds with each other. And it evidently carried over to dealings on other issues. We note that will also be a side benefit in COPE.

If this process can work for us, it can work for your as you seek to implement the New Perspectives program in Alaska.

Thank you for the opportunity to participate in this conference. I look forward to learning some new things with you during these next two days.

FOREST VEGETATION PATTERNS AND PROCESSES IN OLD GROWTH RIPARIAN FORESTS OF NORTHERN, SOUTHEAST ALASKA

Jon R. Martin and Ward W. Brady

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ABSTRACT: The coastal old growth riparian forests of northern southeast Alaska were studied as part of a plant association classification project. Natural variation in these forests is described using field observations, principal components analysis and stepwise discriminant analysis (SDA) of reconnaissance level data from 96 stands. These forests have developed under relatively short, cool, and extremely wet growing season. Soil moisture is generally excessive and fire is absent. Wind is an important factor affecting forest structure. Landslides and snow avalanches on steep mountainslopes and insects are minor, locally important agents of change. Most of these forests are in a climax, old growth condition. This is in sharp contrast to dry, fire influenced ecosystems where much of the complexity is due to an almost infinite successional mosaic. Most of the riparian forests are dominated by large, \widely spaced Sitka spruce (Picea sitchensis), devil's club (Oplopanax horridum), salmonberry (Rubus spectabilis), alder (Alnus spp.), and a lush variety of forbs and ferns. Little variation occurs in the overstory of these forests while much variation occurs in the understory. This is in contrast to the adjacent upland forests where much of the variation occurs in the overstory. While soil drainage is the dominant factor influencing upland vegetation, soil disturbance from flooding appears to be the dominant factor in these riparian forests. At the extremes, highly disturbed sites immediately adjacent to streams are forb dominated while undisturbed old stream terraces are dominated by western hemlock (Tsuga heterophylla)/blueberry (Vaccinium spp.) associations. This gradient can generally be described from most to least disturbed as follows: forb-gravel bar, alder, Sitka spruce/alder, spruce/devil's club-salmonberry, spruce/devil's club, spruce/devil's club/skunk cabbage (Lysichitum americanum), spruce/blueberry-devil's club, spruce/blueberry/skunk cabbage, spruce/blueberry, and finally to western hemlock/blueberry. Understanding and communicating these concepts through the use of ecologically based classification systems will aid resource managers in decisions regarding riparian resources.

HOW TO ACCOMPLISH SOIL AND WATERSHED STEWARDSHIP OBJECTIVES THROUGH INTEGRATED PRESCRIPTIONS

Jerry Boughton

This presentation was delivered in the context of accomplishing integrated resource prescriptions within Forest Service planning and interdisciplinary team processes.

Introduction

Quality resource management. What is it? Leopold would say something to the effect of "intelligent tinkering requires maintaining all the parts". Inherent to the concept of maintaining all the parts is equality of all resource values.

To accomplish quality integrated resource management, there must be resource expertise. Many that have participated in interdisciplinary teams can recall projects where resource expertise was lacking. The players did the best job they could, but because of a basic lack of expertise, some resource values were not recognized and, therefore, never considered.

But resource expertise, in itself, is not enough; by itself, it often breeds advocacy. Individuals involved in an advocacy capacity will have an extremely narrow focus, and be interacting for the sole purpose of forwarding their view of what is best for the single resource they are considered the expert for. Provided one has sufficient funds to hire many specialists, this type of interaction will ensure all resource values are recognized; however, actual integration may never occur. Integration of management actions to maximize the mix of resource values, requires a few more ingredients.

Key Ingredients

Management Climate There must be a prevailing attitude among participants based upon communication foundations such as mutual respect, trust, credibility, and humbleness. You rarely hear humbleness mentioned as a positive management trait in management texts, yet without humbleness it is difficult, if not impossible, to accept another' point of view.

In work situations this type of management climate will generally not exist without leadership and accountability. As the Forest Service moves towards implementing the participatory decisionmaking portion of new perspectives concepts, it will be imperative to firmly establish a positive communication atmosphere, not only within the agency but with public participants as well.

Processes Let's assume that Leadership has established a proper management climate for participants to work in. Even with the best work atmosphere, there is little hope for effective project level resource decision making without a process that allows the participants to focus their expertise and creativeness on solving the issues at hand. The key element is objectives. People are producers by nature. There is a natural tendency to give the issue a cursory look, quickly move to a solution, and focus attention on the next issue. Unfortunately, this type of process almost always results in recycling of the issue/solution process, often several times.

To avoid this type of circular and frustrating interaction, complete and explicit outcome expectations (objectives) must be step number one. An effective planning process facilitates the transition from general program goals to specific and explicitly stated project objectives.

Statements such as "Enhancing wildlife habitat", "Maintaining water quality" or "Maximizing timber production" are too often considered objectives and not recognized that they are actually general program goals. While these may be appropriate at Forest level planning, site specific project objectives (that contribute to these general forest goals) must be more explicitly and clearly stated. Examples of project objectives could be:

"The objective is to increase Vaccinium browse availability to X level during years 2-40 as stand 123 develops." "The objective is to produce X amount of sawtimber volume by stand age X." "The objective is to maintain a stable channel profile with 20 pools/mile."

Without clearly stated specific resources objectives that can be rolled over, shook out, and closely examined, it is unlikely there will be true understanding of all resource needs and expectations by all participants. This will result in a lack of commitment to common objectives, which without commitment to common objectives, there is little chance of integrating resource actions.

Two old adages come to mind here; "Sometimes you have to go slow to go fast", and "If you don't know where your going, any road will get you there".

Developing and actually writing out site specific resource objectives allows understanding of resource needs by all participants, and facilitates individual resource objectives to become "common objectives". Once site specific "common objectives" are established, participants can then focus their energies, as a team, on the integrated actions to best meet them.

Documentation To aid the "objectives to integrated actions" thought processes and to provide clear instruction for imple-

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menting the management decisions, the final ingredient necessary is a method to clearly document the thought processes: -What resources/conditions we have to begin with. -What do we want to have (Common objectives - "Desired future condition" or "target stands" are the new buzz words). -What actions in what sequence are necessary to meet these objectives. -How should we monitor to ensure we have met our objectives.

This documentation is the basic format of a "PRESCRIPTION".

Within the agency we have the vehicle for doing this job of documentation (silvicultural prescriptions, the new buzz title is Integrated Resource Prescriptions). We have the direction of when to develop these (during project level NEPA planning), how to develop them (Interdisciplinary), and who has primary responsibility for developing them (Silviculturists).

Why a silviculturist? In our quest for quality management the Forest Service recognized, early in the 1970's, the need to have individuals that possess the skills and resource understanding to clearly state objectives and integrate vegetation management actions to meet those objectives. The title these positions were given was "Silviculturist". Individuals carrying this title have received graduate level training approaching a masters degree in silviculture and are tested to ensure competency. There are two Nationally recognized programs the Alaska Region utilizes to train Silviculturists. One is the Continuing Education in Forest Ecology and Silviculture (CEFES) completed at the University of Montana, University of Idaho and Washington State University. The other is the Silviculture Institute which is completed at the University of Washington and Oregon State University.

Training received in these programs for the purpose of providing primary expertise is in the following fields:

Forest Ecology Silvicultural Prescription Preparation Autecology Silvics & Silvicultural Practices Synecology Decision Making & Problem Solving Dendrology Growth & Yield Modeling Plant Anatomy Economic Analysis Plant Physiology

Training received for the purpose of having a general working knowledge that will facilitate integration is in the following fields:

Soils Watershed Mgmt Geology Forest Economics Botany Fisheries Mgmt Genetics Forest Pathology Statistics Wildlife Mgmt Planning Forest Entomology Visual Mgmt Computer Science Logging Systems Resource Laws

The testing or certification process that follows involves defense of a thesis prescription before an interdisciplinary certification panel. This prescription and defense must meet Nationally established standards before an individual is certified as a Silviculturist. Once certified the Silviculturist is expected to maintain their expertise & must be recertified at least every four years.

The Alaska Region is making significant strides establishing a cadre of silviculturists in the proper positions to accomplish integrated prescription development in the planning processes.

Since April 1990, six individuals have either been recertified or certified for the first time in the Alaska Region. Two individuals will present certification prescriptions to the Regional Certification Panel in May 1991, and there is high interest in the 1991-1992 training program.

Additionally, Silviculturist positions are being established as planning team members on each of the planning teams in the Region. Managers are moving quickly to fill these positions with qualified individuals.

Silvicultural Service

What is the exact service silviculturists provide and how does it aid the planning? Silviculturists provide three basic services:

1. Provide expertise in the application of vegetation management. 2. Provide general vegetation inventory information to the planning team. 3. Provide clear and defensible documentation of the teams integrated management decisions in the form of site specific Integrated Resource Prescriptions.

Integrated Resource Prescription Outline

Integrated Resource Prescriptions are composed of five basic elements: 1. A brief site description. 2. Management Direction (general program goals). 3. Specific site objectives (desired future condition). 4. Treatment sequence that best meets direction/objectives. 5. Monitoring needed to ensure implementation meets direction/objectives.

Integrated Resource Prescriptions serve to concisely display the complete logic process of our management decisions. They display how the management actions not only support general program goals, but also how they directly tie to site specific resource features and meet the site specific resource objectives. The integration of actions to accomplish all resource objectives is readily apparent. Finally, they provide the detailed sequence of treatments which serves as a roadmap for proper implementation followed by outlining necessary monitoring.

Resource Management Situations in the Alaska Region where Integrated Prescriptions will assist accomplishing Soil and Water stewardship.

Windfirm Streamside Management Zones

First you will notice I refer to these areas as Streamside Management Zones and not buffers. I personally feel the word "buffer" is an inappropriate term for professional land managers. A decision to have no activity is in fact prescribing management. Therefore, I prefer Streamside Management Zones (SMZ) whether there is activity in the zone or not.

Wind and resultant windthrow is a major forest disturbance force in southeast Alaska that must be reckoned with when dealing with Streamside Management Zones. I have heard individuals, both within and outside the agency, almost casually shrug this off with statements such as "it's alright if it blows down since it's providing Large Woody Material into the stream". I have difficulty accepting this depth of analysis as quality resource management. Recognizing that the SMZ is at risk to windthrow, the question then becomes: How much blowdown is acceptable in this particular situation? Is 10% of the SMZ acceptable? How about 50%? Is 100% in one storm event too much? What can be done to minimize the risk?

Harris(4) and others(1) have provided us with some basic information for dealing with windthrow hazard. There are two major points brought out in this information.

First, there is no guarantee for providing wind-firmness. The best that can be done is to recognize the factors contributing to windthrow risk and deal with them appropriately to minimize the risk. In a slide tape program (9) authored by George Wingate and Terry Mooster, and published by Oregon State University Forestry Media Center, these factors are discussed and placed in the context of a formula for estimating SMZ percent survival from windthrow for the Orgeon western Cascades. While the coefficients would undoubtedtly vary for southeast Alaska, the factors are probably relevent.

Secondly, width of the SMZ is not one of the factors for wind-firmness. Unless the edge of the SMZ is tied into a factor that is likely to increase its wind-firmness, such as varying species composition, increased soil drainage, less exposure to wind, etc., adding additional width will only place more forested area in risk of wind-throw.

I would like to take this opportunity to raise the caution flag to what I see as a shortcut to the windthrow thinking processes in southeast Alaska. This has to do with "feathering" edges for wind-firmness. When reviewing the edges of natural wind-throw areas, one often sees what appears to be a gradation in tree heights. This is a logical phenomenon to see. A ten foot tall tree is likely to be more wind-firm than a one hundred foot tall tree. Also, more subordinate vegetation will be mashed to the ground at the leading edge of a wind-throw where fifty trees per acre have been wind-thrown than on the tail edge where five trees per acre have been wind-thrown. However, it is a logic breakdown to assume that this result, if duplicated, will add to the windfirmness of the adjacent stand. Vegetation manipulation for wind-firmness should be accomplished in the context of the established risk factors.

While application of a feathering effect may be useful in some specific circumstances, rote application of this technique is inappropriate.

Site Specific Class III Stream Needs

The current method of stream classification in southeast Alaska is Class I - anadromous, Class II - resident fish, Class III - everything else. This provides an extreme variation in class III streams from extremely high volume/velocity boulder laden V-notches to low volume meandering trickles. This in turn provides managers with the challenge of determining site specific resource objectives and/or protection needs. Again, rote application of management strategies to Class III streams is impossible with this extreme variation.

Sediment Contributions To Streams

Surface erosion and accelerated sediment, as a result of surface disturbances from timber harvest, is a major concern in many parts of the country. Due to the substantial organic layer prevalent in southeast Alaska, sediment contributions from water overland flow and surface erosion are highly unlikely. The organic layer not only provides absolute protection (6) from surface erosion processes, but can also be an effective filter to trap any sediment generated from exposed areas. Stephens (1966) stated that normal cable yarding bares little mineral soil and that mineral soil (the primary potential sediment source) is commonly exposed only on tractor and highlead swing roads, borrow areas, road cut and fill slopes, and landslide tracks.

Historically, most investigators of timber harvest/soil and watershed relationships have agreed that roads generally create a disproportionate share of accelerated erosion(8). In southeast Alaska, a high proportion of roads are valley bottom locations with rock overlay construction. Also, southeast Alaska streams have a large natural variability in stream sediment transport regimes. Because of these two factors, there has been no definitive southeast Alaska study quantifying stream sediment input from road construction activities to date. A study in the Indian River drainage concluded there was no statistically significant change in sediment transport detected in this large southeast Alaska watershed with 30% of it harvested and associated road construction (3).

It should be recognized however, that potential exists for creating sediment sources and effectively transporting that sediment to the streams through harvest and road construction activities. While timber harvest and road construction activites use best management practices to minimize sediment input, some aspects of these activities that could be considered are:

Logging Systems

Highlead: Appropriate pre-planning of landing location and design to fully utilize machine external yarding capabilities can result in less landing and temporary road construction. Additional landings added during logging administration serviced with temporary roads can have a greater potential for off site sediment delivery than a fully designed transportation/logging system.

Skyline: When matched appropriately to topography, skyline logging systems can provide one end or full log suspension. This obviously can reduce potential off site sediment deliveries, especially if harvest activities are adjacent to slides or exposed mineral soil in road cuts and fills. This equipment provides the potential capability to "fly" logs across riparian areas and lateral yard around within-unit inclusions or leave areas.

Shovel: The Chatham Area has successfully applied this logging system with very acceptable results. It provides opportunities to yard around inclusions or leave areas and highly variable streamside management zone edges.

Road Management

Road closure is a reasonably new consideration in the Region. How should the road be closed? What is the closure objective? Culvert removal can be an expensive activity; yet if culverts are not removed and the road "put to bed", the system will require continued maintenance. Removing culverts can return an undisturbed stable vegetated situation to a disturbed potential sedimentation source. Opportunity exists to coordinate access with a variety of other resource objectives. Many streams in southeast Alaska with recognized high bedload transport are now being crossed with bridges or bottomless arches to allow unrestricted bedload dynamics to occur. Stream crossing design that allows natural stream processes to continue, and require low levels of maintenance, will in the long run minimize sedimentation effects.

Stream Temperature

Research results have consistently shown that summertime temperatures of small streams can be increased when streamside forest cover is removed or altered to allow additional solar input.

A major question for Alaska is how much shade is needed. A concern in most Washington/Oregon Pacific Coast streams is increased summertime temperature (2). Due to stream orientation, previous effects, and general climate, summertime stream temperatures in that area approach maximums for fish growth or survival and stream shade reduction is a further negative impact. While this situation may exist in various Alaskan streams, it has been suggested that this is not universal and that in fact habitat could be improved in some streams through increased temperatures. This being the case, shade and solar input, in souteast Alaska, should be managed on a site specific basis relative to identified habitat needs.

Recent legislation has for the most part precluded options to manage solar input into class I streams or class II streams that flow into a class I. However, recognition of these relationships and application of management options continues to exist on a portion of the class II and all class III streams.

Large Woody Material

There are a substantial number of acres in Alaska that were harvested to the stream banks in the last thirty-five years. Many of these are currently vegetated with alder stands or extremely dense conifer stands. What is the desired condition of this streamside vegetation? How should it be managed to meet riparian needs over time?

Many studies have established the need for large Woody Material in streams. It is an important component to bedload dynamics as well as providing structure, habitat, and as nutrient sources. Existing riparian stands of extremely dense conifers or alder will require a long period of time (150-200 years) to develop large material for recruitment. Management of these existing riparian stands could produce the same sized material for recruitment much sooner (70-100 years). McMahon and Reeves (5) noted that managing riparian vegetation is managing fish habitat, and that active manipulation of riparian vegetation to speed up successional processes and narrow the time frame for future delivery of large dead trees to the stream will aid in maintaining and improving fish habitat.

Some placement of large woody material in streams determined to be deficient has occurred in Southeast Alaska. Several of these attempts have used small material banded together with wire rope and anchored to the shore. Studies have indicated that transport, usefulness in the system, and longevity of this material are better attained with a "natural" piece rather than an artificial or constructed piece. Large material with root wads attached are the best. Insertion of natural pieces with root wads attached has been accomplished through the use of logging equipment, including skyline cable systems. The potential exists to accomplish this in a cost effective manner when coordinated with adjacent harvesting.

10 Year Old Pavlof River New Perspectives

I would like to share some Alaska Region ten year old "New Perspectives" with you. This is a specific streamside management zone that received a group selection harvest. In my opinion, this project represents what new perspectives is all about because:

1. It was new and many people did not think it would work.

2. The folks planning it did a complete job of recognizing the resource direction for fisheries, recreation, and timber, and the site specific resource values/obstacles of a canoe route and windthrow potential.

3. An innovative (for the time) integrated vegetation management plan was developed that best met all resource objectives.

This highly susceptible windthrow spruce flat had approximately 30% of the stands timber volume harvested with long, narrow group selection harvest system application oriented perpendicular to the prevailing wind direction. These groups ended before they would be visible from the river, and removal

was done in the winter on snow to avoid soil disturbance to this very sensitive system.

The recreation values of the canoe route are intact. Water quality was maintained and soil disturbance avoided during the operation. Timber values were realized with the removal and subsequent regeneration of an appropriate portion of the stand. Windthrow damage has not occurred to date. For an aerial view of this project see page 19 of the Alaska Region pamphlet titled Fish in the Forest(7).

Our limitations to objectively recognizing our resource values and developing logical solutions are no greater, and in actuality, probably less today than when this project was designed. Often our limitations are self imposed. It has been stated many times that New Perspectives is not a program in itself but an attitude.

Summary

The theme of the watershed 1991 conference is New Perspectives. New Perspectives has erupted in the past few years from what a few people were calling Ecosystem Management. Momentum has grown as more and more people have become involved.

In the areas where New Perspectives was born, some leaders have recently issued cautions. They have not said to not proceed with New Perspectives, but they are stressing to do it intelligently, based upon identified resource needs, and upon sound logic. New Perspectives is not simply trying something different for the sake of being different. I believe Leopold would consider that foolish tinkering instead of intelligent tinkering. Intelligent tinkering must be based upon: -A comfortable understanding of the biotic system we're dealing with. -A clear and specific vision of how the system needs should look over time. -All the collective corporate knowledge we can muster determining how to accomplish the desired future conditions to meet all resource objectives. -Lastly, a system to ensure our logic is sound.

Integrated Resource Prescriptions are the agencies tool to not only aid us in our logic processes, but to document that logic and provide a specific roadmap so the intelligent tinkering that is planned is appropriately carried out.

My challenge to the Watershed 1991 participants is to ensure you all take on a personal responsibility to contribute to establishment of the attitudes and the processes needed to move New Perspectives ahead quickly, professionally, and as Leopold would say, "intelligently" in the Alaska Region.

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Primary Ecosystem Development Following Glacial Recession in Southeast Alaska

Freeman R. Stephens and Earl Alexander

ABSTRACT: Sitka spruce-western hemlock forests have developed on drift from glaciers that have been retreating for a little more than 2 centuries in Glacier Bay and the Mendenhall and Herbert Valleys. There is an alder stage of succession on well- to moderately well-drained soils of moraines, but not on more droughty soils of kames and outwash plains. Tensiometer measurements in a pair of 40 to 50-year-old ecosystems indicate that the soil supporting Sitka alder remains wetter through the summer. Nitrogen accumulates in soils on the alder path of succession at about 32 kg/ha yr, compared to only about 12 kg/ha yr in soils lacking an alder stage. Due to the greater accumulation of N, spruce tree growth rates are higher in stands that pass through an alder stage of successional development.

Many glaciers in southeast Alaska have termini near sea level which have been retreating for about 2 centuries (Lawrence, 1958; Viereck, 1967). Plant succession and soil development have been studied on the recessional moraines and kames of some of these receding glaciers (Cooper, 1923; Chandler, 1942; Crocker and Dickson, 1957; Crocker and Major, 1955; Ugolini, 1966, 1968).

The paths of plant succession depend on soil drainage. Never-the-less, the steady-state plant communities are spruce-hemlock forests on all moderately-well to excessively-well drained soils of coastal glacial drift north of about 57°N latitude, regardless of path. Western hemlock (*Tsuga heterophylla*) (The botanical nomenclature follows Hulten 1968) and Sitka spruce (*Picea sitchensis*) are the dominant trees.

The mature soils of the spruce-hemlock forest in southeast Alaska are Spodosols (Stephens 1969). Even the shallowest well-drained soils seldom dry to tension of 10 kPa in this damp climate (Patric and Stephens, 1968). Stephens et al. (1968) found that Sitka spruce growth was closely related to soil drainage and, within the well- and moderately well-drained group of soils, to soil depth to bedrock and to soil texture. Sitka spruce growth was well correlated with soil nitrogen content.

Preliminary observations indicated three different successional paths on moderately well- to somewhat excessively well-drained deglaciated sites in the Mendenhall and Herbert Valleys near Juneau. Succession in the most extensive chronosequence on drift (designated C1, or Chronosequence One) passes through a Sitka alder (*Alnus crispa ssp. sinuata*) stage. Chronsequence Two (C2) develops on bare rock and, at the time C1 is in the alder stage, supports scattered spruce, willows (*Salix spp*) and Sitka alder growing on crevices and pockets of drift. Chronosequence Three (C3), although on deep drift, lacks an alder stage. All three successional sequences pass through a Sitka spruce-dominated forest stage before reaching western hemlock-dominated forest. Judging by soil drainage and depth, C1 ecosystems will ultimately develop into mature forest ecosystems with tallest Sitka spruce site index (height in meters at 100 years), around 46; those of C2, 25-37; and those of C3, around 40.

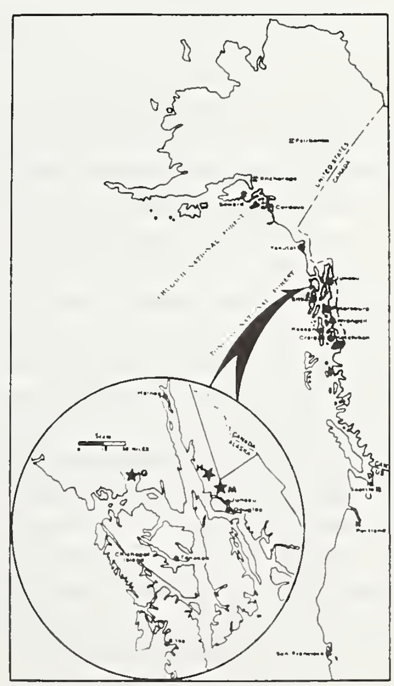

Figure 1. Location of study areas: H, Herbert Valley; M, Mendenhall Valley; G, Glacier Bay.

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A study was initiated to: (1) ascertain why the alder stage develops in C1 but not in C3 ecosystems, (2) compare rates of soil nitrogen accumulation, and (3) determine Sitka spruce growth rates in C1 and C3 ecosystems.

THE CHRONOSEQUENCES

Soil characteristics and vegetation at important stages of development for the three chronosequences are outlined in Table 1. Because of the variable development in C2 (noted by Cooper, 1923), it is not discussed in detail.

Table 1.--Some properties of three chronosequences in the Herbert and Mendenhall Valleys and at Glacier Bay.

Chrono-sequence	Soil Characteristics	Dominant Vegetation at 40-50 years	Dominant Vegetation at 150-200 years
One (C1)	Deep, moderately-well to well-drained drift or at least several centimeters of drift over bedrock.	Dense thicket of Sitka alder and willows with scattered overstory cottonwood. Sitka spruce struggling through the thicket (Fig. 2).	Closed canopy of Sitka spruce and a few cottonwood. Suppressed hemlock numerous. Few shrubs. Complete carpet of mosses.
Two (C2)	Bare rock with or without a scattering of drift. Pockets of drift in crevices.	Lichens and mosses covering most of the rock. Individual spruce trees and clumps of Sitka alder and willow in crevices.	Variable. Usually open, slow-growing spruce stand with alders, willows, and moss-covered rock.
Three (C3)	Deep, well to somewhat excessively well-drained drift.	Slow-growing Sitka spruce, cottonwood, and willows with lupine, lichens, and mosses (Fig. 3).	Same as C1, except trees are smaller.

This is the most extensive chronosequence in the three areas (Fig. 1). The striking feature is the dense Sitka alder-dominated shrub stage that precedes the Sitka spruce forest (Fig. 2.). The vegetative succession at Glacier Bay was described by Cooper (1923). In the Herbert and Mendenhall Valleys, the succession is essentially the same, except that Dryas is lacking and Sitka spruce closes canopy sooner, probably because of the proximity of conifer seed sources on the valley walls. Alder remains are still abundant in C1 ecosystems about 125 years old. The alder stage has been shown to add significant quantities of nitrogen to the soil (Crocker and Major, 1955; Crocker and Dickson, 1957).
The soils range from about 10 to 60 cm of drift over bedrock to deep, moderately well- to well-drained drift. The deep drift either has a relatively impermeable layer or is relatively shallow to a water table. Under shallow drift, bedrock retards percolation and forms a drainage restriction. All C1 soils appear to have abundant available moisture

Figure 2. The C1 tensiometer site, 58°24'29"N, 134°32'53"W. Abundant alder.

Chronosequence Three (C3)

This chronosequence is on well- to somewhat excessively well-drained moraines and kames (editors note: in the Mendenhall Valley, mostly on outwash plains). It is only on deep drift with neither drainage restrictions nor shallow water tables (Fig. 3). After the surface is somewhat stabilized by mosses and lichens, a cover of Sitka spruce, cottonwood (*Populus balsamifera ssp. trichocarpa or ssp. balsamifera)*, willows, dwarf fireweed (*Epilobium latifolium*),and lupine (*Lupinus nootkatensis)* develops. The spruce and cottonwood grow slowly and do not form a closed canopy to eliminate the lupine until after 100 years. As the moss layer develops, mountain hemlock (*Tsuga mertensiana*), western hemlock, Labrador tea (*Ledum palustre ssp. groenlandicum*), wintergreen (*Pyrola spp*), blueberry (*Vaccinium spp*), and other species appear. By 200 years, a timber stand dominated by Sitka spruce with a minor component of cottonwood and many suppressed western hemlock has developed. A complete carpet of moss, dominated by Rhytidiadelphus and Hylocomium, covers the ground with scattered understory plants including blueberry bunchberry (*Cornus canadensis*), and five-leaved bramble (*Rubus Pedatus*). There is no alder stage in this chronosequence.

Although 40- to 100-year-old ecosystems with little or no alder are evident in both the Herbert and Menhenhall Valleys, they were not found in Glacier Bay areas studied in this investigation.

At the C3 tensiometer site (Fig. 3), there is no uniform canopy level; the vegetation has a ragged appearance, with small openings, low vegetation in full light, and some lichen-covered and bare soil. Plants present, in approximate order of cover, include mosses, willows, Sitka spruce, lichens, cottonwood, lupine, wintergreen and traces of western hemlock, Sitka alder, blueberry, mountain heath (*Phyllodoce spp*), and grasses.

Figure 3. The C3 tensiometer site, 58°25'08"N, 134°35'15"W. Spruce, willows, cottonwood, and openings.

Precipitation data were available from a nearby cooperative U.S. Weather Bureau Station (Fig. 4).

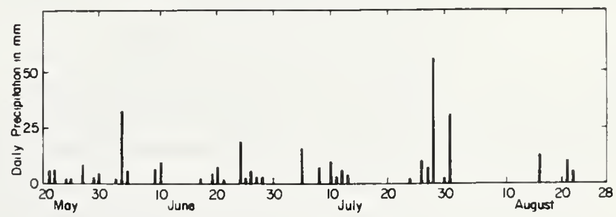

Figure 4. Precipitation in Juneau, 1968.

METHODS

Field studies were conducted intermittently between March and October 1968. Sites of different age and chronosequence were visited at Glacier Bay and in the Herbert and Mendenhall Valleys. Plant nomenclature follows Hulten (1968).

In the Mendenhall Valley, mercury manometer tensiometers were installed in drift with 40- to 50-year-old C1 and C3 ecosystems. The porous cups were placed at 10 cm depth, three at each location. In the C3 ecosystem, the porous cups were placed in a row, about 60 cm between cups. One cup was placed under a small spruce, one near its "drip line", and one in a small opening. In the C1 ecosystem, the cups were placed on the side and near the top of a low, alder-covered moraine. Tensiometers were read intermittently, although an attempt was made to read them just before and after rains.

At the C1 tensiometer site (Fig. 2), Sitka alder with a minor component of willow formed a complete canopy cover about 5 m high. Scattered, suppressed Sitka spruce and western hemlock and dominant cottonwoods indicate the successional trend. Wintergreen was the most common forb, along with a few ferns (*Dryopteris dilatata*) ssp. *americana*). Mosses and grasses made a nearly complete ground cover.

A soil pit was dug at each site, and the profiles described (Soil Survey Staff, 1951) and sampled. Bulk samples were analyzed at the University of Alaska for chemical properties. Methods of analysis were those of the National Cooperative Soil Survey (Soil Survey Staff 1967). Nearly undisturbed 45.25 cm3 soil core samples were extracted in duplicate for bulk density determination.

Sitka spruce growth rates were determined by two methods. Dominant trees were felled and cut into 1.5 or 3 m blocks. Rings were counted at each section so the tree's past height growth could be reconstructed. Stump diameter growth was determined by measuring its increment at ten-year intervals. Present ages and heights of other dominant spruces were ascertained by increment corings and Abney level and tape.

RESULTS AND DISCUSSION

Soil Properties

Morphology of the soils at the two tensiometer sites was very similar (Table 2). Horizons, depths, textures and colors were nearly identical, except for the 0 horizons. Beneath the alder at the C1 tensiometer, the O-horizon was 6 cm thick, black, and well decomposed. Beneath the young spruce at the C3 tensiometers, the 0 horizon was just 3 cm thick and only slightly decomposed. Textures in both profiles were stony, very gravelly loamy sands throughout, with 50 to 60 percent coarse fragments estimated by volume. (editor's note: although the textural classes might be the same for most horizons in the soils of both sequences, there is considerable textural range within the classes, and there may be strata of

Table 2. A pedon (Typic Cryorthent)[a] at the C1 tensiometer site; described on May 22, 1968.

Horizon	Depth (cm)	Description [b]
Oi	6-4	Litter of alder leaves, twigs, and grass.
Oa	4-0	Black (5YR 2/1) amorphous organic matter, abundant fine roots; clear wavy boundary
E	—	Very thin trace of clean sands; also, clean sands in the lower part of O-horizon (C3 description identical).
Bs	0-7	Dark grayish brown (10YR 4/2) with blotches of brown to dark brown (10YR 4/3), stony, very gravelly loamy sand; many fine, medium, and coarse roots; gradual, wavy boundary (C3 description identical).
BC	7-12	Dark grayish brown (2.5YR 4/2) stony, very gravelly loamy sand; common fine and medium roots; gradual, wavy boundary (C3 color is dark gray, 2.5Y 4/1).
C	12-60	Dark gray (5Y 4/1) stony, very gravelly loamy sand; few fine and medium roots; coarse fragments coated on top with fine soil, but clean underneath (C3 description identical).

[a] It is unlikely that enough Al and Fe have accumulated in the Bs horizon for it to be a spodic horizon (Soil Survey Staff, 1990, "Keys to Soil Taxonomy", Soil Management Support Services, Tech. Report 19, VPI Press, Blacksburg, VA).
[b] Colors are for moist soil, Munsell notation.

finer texture beneath the sola of soils in the C1 sequence) Little or no expression of structure was evident. Surface (Bs) horizon bulk densities were 1.6 g/cm3 at both tensiometer sites. C-horizon (30 cm depth) bulk densities were 2.1 and 1.8 g/cm3 at the C1 and C3 tensiometer sites, respectively. Horizon development is weak in these young soils. B horizon designations are based on the thin but evident E horizons, and the fact that the nearby 200-year-old and mature soils of similar drainage all have well-expressed Podzol profiles (Stevens, 1963; Gass and Heilman, 1967). Differences in soil chemical properties appear to be due to differences in vegetation (Table 3).

Table 3. Some soil chemical properties of two young soils in the Mendenhall valley.

Soil	Hor	Depth cm	pH	Total N [a] g/kg	Extract P percent	Exchangeable Cations CEC [b]	Ca	Mg	K	Base Sat. %
						----meq/100g----				
Site 1	O	6-0	4.1	8.50	0.04	35.0	8.38	2.15	.28	31
	Bs	0-7	4.2	0.38	0.04	2.0	0.04	0.10	.10	12
	BC	7-12	4.5	0.06	0.07	4.1	0.31	0.00	.06	9
	C	12-60	5.2	0.02	0.05	2.2	0.60	0.01	.04	30
Site 3	O	3-0	4.9	5.00	0.11	42.4	22.36	2.67	.27	60
	Bs	0-7	5.0	0.24	0.07	2.4	1.09	0.08	.05	51
	BC	7-12	5.1	0.11	0.09	2.4	0.56	0.10	.06	29
	C	12-60	5.9	0.04	0.07	2.1	0.73	0.08	.06	40

[a] Nitrogen by the Kjeldahl procedure.
[b] Cation-exchange capacity.

Total nitrogen is greater in the C1 soil, about 1.0 Mg/ha versus about 0.5 Mg/ha in the C3 soil. Other nutrients seem to be slightly higher in the C3 soil. Base saturation and pH are lower in the C1 soil, confirming the acidifying effect of alder noted earlier (Crocker and Major, 1955). Soil chemical properties do not appear responsible for the lack of alder in C3.

Soil Moisture

Within each area, the drift deposits that form the soils in C1 and C3 ecosystems are lithologically (and mineralogically) similar. The lack of an alder stage in C3 cannot be explained by soil nutrient relations, lack of seed source, or climate, as there are no significant difference in these features between young C1 and C3 ecosystems in each area. Relatively large differences in precipitation and slope aspect are presumed to be insignificant, due to the persistantly high humidity. The absence of an alder stage on C3 soils can be explained by moisture relations. All C3 soils have profiles that appear more "droughty" than those of C1. The tensiometer records confirm this observation (Fig. 5). Soil moisture tensions (average of three) never exceeded 30 kPa in the C1 soil, while the C3 tensiometers exceeded 30 kPa on two occasions. Average soil moisture tension in C1 did not exceed 10 kPa until mid-July. Maximum individual tensiometer reading were 66 kPa on July 25 in C3 and 42 kPa on August 15 in C1.

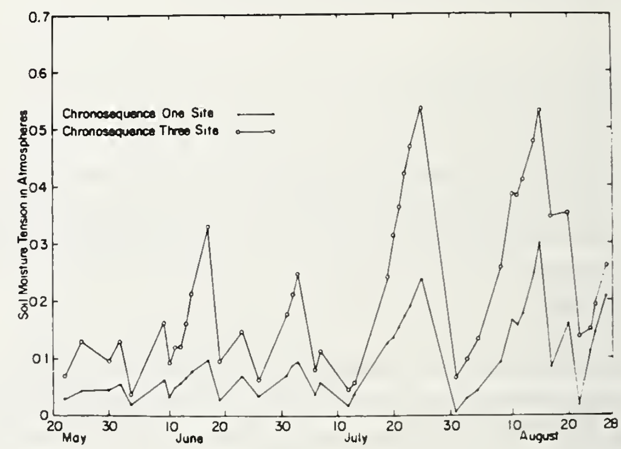

Figure 5. Average soil moisture tensions at 10 cm depth in soils of C1 and C3 ecosystems on 40- to 50-year-old moraines near Juneau. Each plotted point is the average reading of three tensiometers. Differences between C1 and C3 tensions are statistically significant on each reading date except July 14.

During dry periods, C3 tensions were generally more than double those of C1. As the season progressed, there was a definite trend for C1 peak tensions to approach those of C3. Ratios of C3 to C1 tension peaks declined from 3.4 in mid-June, through 2.7 in early July, 2.3 in late July, and 1.8 in mid-August, to 1.2 in late August. Rates of moisture tension increase (steepness of ascending slopes in Fig. 5) remained fairly consistent in C3, but showed a definite increase in C1

increase (steepness of ascending slopes in Fig. 5) remained fairly consistent in C3, but showed a definite increase in C1 as this abnormally dry season progressed. This trend was related to the general lowering of the water table, evidenced by reduced stream flow and drying up of smaller streams in the area during the same period. It seems that, early in the season, much of the water demand of the alder stand was obtained directly from the water table and/or its capillary fringe. As the water table lowered, less water was available from this source and a higher proportions had to be obtained directly from upper profile soil moisture storage.

There was usually little difference in readings among the three C1 tensiometers. During wet periods, readings were usually within a spread of 0 to 3 kPa. During periods of relatively high tension, readings were usually within 10 kPa, although on one occasion the difference reached 19 kPa.

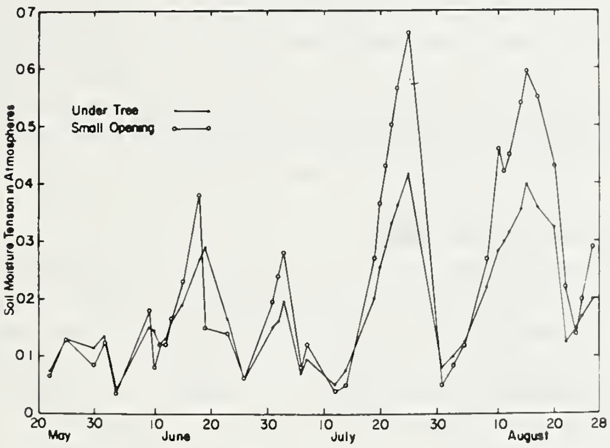

Figure 6. Soil moisture tensions at 10 cm depth in a C3 ecosystem under a small Sitka spruce and in a small opening 1.2 m away.

Differences in readings were much more marked in the three C3 tensiometers (Fig. 6), as there were greater differences in microsite. The tensiometer in the small opening showed the greatest fluctuation, with higher peak tensions and lower minimum tensions, while the tensiometer under the small Sitka spruce showed the least. The tensiometer in the opening, although partly shaded and sheltered from drying winds, would be more representative of the soil at the time of vegetative establishment than the others. Peak tensions on a young, still-bare C3 moraine or kame would be even higher. Peak tensions closer to the surface than 10cm would also be higher. Soil moisture tensions under the Sitka spruce reflect the ameliorating effect of vegetation on upper profile soil moisture.

Although precipitation in the summer of 1968 was lower than normal (Fig. 4), the longest rainless period was 15 days. Fifteen days in the summer without rain is not uncommon in the Juneau area. Moreover, the summer had no "hot spells" as the season high temperature was only 20.6 degree C, so evapotranspirative demand was not high.

Drying of the surface few centimeters in C3 soil seems to have prevented Sitka alder establishment. Cooper (1923) observed that young drift may dry in the surface. Referring to fresh drift in Glacier Bay, he noted: " ... there are periods during the growing season when the coarser superficial layers of soil become relatively dry. For well-established plants this is of little importance, since the deeper layers must always retain an adequate supply, but for recently germinated seedlings the water deficit must frequently prove fatal."

Evidently, the deeper and more frequent drying of C3 drift had a greater effect on and was more deleterious to the Sitka alder than to Sitka spruce, willows, and cottonwood, possibly due to more shallow rooting of the alder.

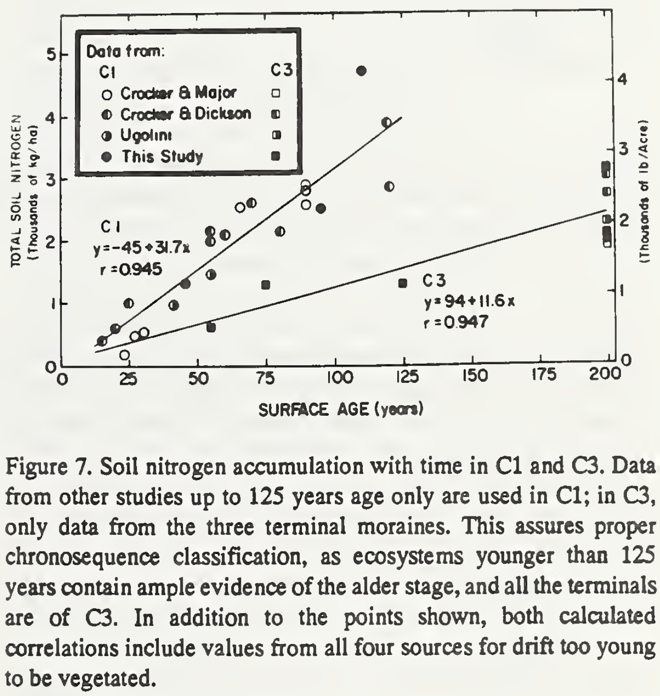

Figure 7. Soil nitrogen accumulation with time in C1 and C3. Data from other studies up to 125 years age only are used in C1; in C3, only data from the three terminal moraines. This assures proper chronosequence classification, as ecosystems younger than 125 years contain ample evidence of the alder stage, and all the terminals are of C3. In addition to the points shown, both calculated correlations include values from all four sources for drift too young to be vegetated.

Soil Nitrogen Accumulation

Soil nitrogen, including 0 horizons, in C1 accumulates at about 32 kg/ha year but only at about 12 kg/ha year in C3 (Fig. 7). This again demonstrates the efficiency of Sitka alder in nitrogen fixation. Organic nitrogen is contributed to C3 soils by lupines, and nitrogen-fixing microoganisms, but their combined effect is much less than that of the alder.

Sitka Spruce Tree Growth in Primary Stands

After the conifer canopy is closed, species composition is nearly the same in both chronosequences. However, they can

Sitka spruce height and diameter growth are greater on C1 soils than on C3 soils (Fig. 8 and Fig. 9). Growth in these young ecosystems is slow compared to even-aged timber on mature soils of similar drainage, where dominant Sitka spruce exceed 45 m in 100 years (Stephens et al., 1968). Soil moisture, even in C3, appears ample for rapid growth.

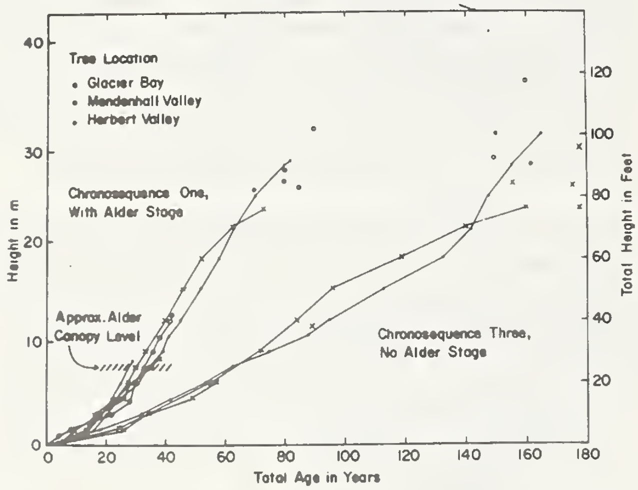

Figure 8. Dominant Sitka spruce height growth in primary ecosystems on young drift near Juneau. Plotted points connected by lines are sectioned trees; those not so connected are individual trees where present height and age were measured.

Growth of even-aged timber on mature soils in southeast Alaska was found to be well correlated with soil nitrogen availability (Stephens et al., 1968). Similarly, it seems that nitrogen added by the alder stage is the reason that spruce grow faster in C1 than in C3 ecosystems.

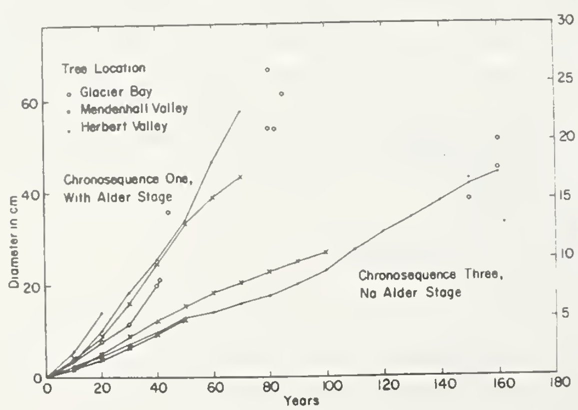

Figure 9. Dominant Sitka spruce diameter growth in primary ecosystem on young drift near Juneau. Plotted points connected by lines are diameters inside the bark of felled tree stumps; those not so connected are diameters outside the bark at 1.4 m above the ground (DBH). DBH outside the bark is usually about 2.5 cm less than stump diameter inside the bark.

Sitka spruce growth differences are relatively low within chronosequences, in spite of the difference in parent materials and climate within the three areas. In addition, trees measured in C1 ecosystems were on moraines and side slopes of varying aspect.

CONCLUSIONS

Soil drainage in drift of the Mendenhall and Herbert Valleys greatly influences primary succession and, consequently, soil development. For instance, C1 ecosystems, because of the alder stage, accumulate greater quantities of nitrogen and are more productive than C3 ecosystems.

Mature equivalents of these young ecosystems evidently reflect their early history. Those developed from C1 have dominant Sitka spruce site indexes of about 46 m at 100 years. Those from C2 that have 5 to 25 cm of mineral soil over bedrock have site indexes of about 37; those with 0 to 5 cm of mineral soil, about 27. Those from parent materials equivalent in drainage to C3 have site indexes of about 40. The relative productivity ranking evident in the primary ecosystems holds for their mature equivalents.

ACKNOWLEDGMENT

The editor (E.B. Alexander) is grateful to D.B. Lawrence, Professor Emeritus, University of Minnesota, for alerting him to the existence of Stephen's manuscript and encouraging him to edit it for publication.

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EPILOGUE

Freeman Stephens had many innovative ideas and was very energetic in pursuing evidence to test those ideas. Having inherited a manuscript he prepared a short time before his death in 1969, I have attempted to preserve his ideas that have the firmest support.

The greatest uncertainty I encountered was in interpreting Stephens' landform and stratigraphic designations. He mentioned "push" moraines and till, but neither kames nor outwash. My experience in the Mendenhall Valley has been to find the alder succession (C1 ecosystems) on moraines (recessional) and the lupine succession (C3 ecosystems) on outwash plains. Therefore, being uncertain of Stephens' landform and stratigraphic interpretations, I have translated his "till" as "drift".

Stephens' greatest contribution was in showing the differences in soil moisture in 2 soils with different successional paths. He installed tensiometers at 40- to 50-year-old sites that still had alder and nonalder plant communities; thus it was certain that they represented both alder and lupine successional sequences.

Stephens' analyses of productivity and nitrogen accumulation differences are not so clearcut, because he had the notion that he could determine the successional path that an older site had gone through based on the spruce site index. Differences for sites on surfaces < 125 years old, where abundant alder or lupine plant communities are still present, are unequivocal (for example, N in Table 3). However, differences that include data from older plant communities (for example, Fig. 7) are questionable to the extent that the supposed successional paths of older sites, with abundant alder or lupine no longer present, were determined by spruce site index rather than from geomorphic or soil properties.

B.T. Bormann and R.C. Sidle (1990, J. Ecol. 78: 561-578) found, in a more recent study of soils on moraines at Glacier Bay, that nitrogen accumulated at 28 kg/ha yr in the alder stage of succession and 8 kg/ha yr in spruce stands on older but similar moraines. This first figure corresponds closely with the 32 kg/ha yr that Stephens' reported for the alder path, but the second is closer to that he reported for the nonalder (C3) path. It is possible, if there was an alder stage in the succession to spruce stands on the older moraines at Glacier Bay, that nitrogen accumulation rates are low (about 8 or 12 kg/ha yr) in spruce stands on older (somewhat > 125 years) moraines regardless of the successional path. More studies may be required to adequately test the validity of Stephens' assumption of residual effects for 100 years or more following an alder stage of succession.

I feel that Stephens' has made a valuable contribution to our understanding of plant succession on glacial drift. It is unfortunate that he could not have revised the manuscript himself.

Earl B. Alexander

SOUTHEAST ALASKA FORECASTING PROBLEMS

Joel C. Curtis

ABSTRACT: Southeast Alaska faces a set of unique forecast problems that are based on the combination of physiography and climate. Solutions to these problems in the near future can be accomplished by improved detection of weather systems by acquiring additional and improved observations. Improvements under The National Weather Service Modernization and Associated Restructuring (MAR) and the establishment of offshore buoys could provide better forecasting services to the public, government, and commercial interests of Southeast Alaska.

I. Introduction

Southeast Alaska has a unique and interesting climatological regime. It has predominantly a maritime environment which is periodically invaded by continental arctic air-masses in winter. The maritime influence is well demonstrated by the lack of surface temperature fluctuation both on an annual and diurnal basis. Southeast Alaska is known for both its frequent cloud cover and spatial and temporal variability of precipitation. A "sunny" day is always cherished by the local population.

For the purpose of this paper, Southeast Alaska will encompass the entire Weather Service Forecast Office (WSFO) Juneau forecast area of responsibility, which includes the are from Dixon Entrance to Cape Spencer and also includes the area known as the Eastern Gulf Coast to Cape Suckling (see Figure 1). This area at the northeast corner of the Pacific Ocean is dominated by high mountains paralleling the coast that rise in most cases directly from sea level. Most of this region is known as the "Alaska Panhandle" which has many inland channels of tidewater that are known as "the Inside Passage" with fiords and gaps in terrain that extend further inland. As can be seen from Figure 1, the local weather regimes for Southeast Alaska are dominated by orographic forcing by westerlies and ageostophic surface flow through channels (along the channel as opposed circular around pressure systems). These features of ocean, mountains, gaps, and channels are the key to the complexity of Southeast Alaska's weather.

WSFO Juneau has varied station programs that address the weather fore- casting needs of both the private citizens and commercial interests for Southeast. Transportation is limited to marine and aviation since there are no roads are between population centers. Due to this situation, the Marine and Aviation Programs are strongly emphasized at the forecast office. The Public Forecast Program shares the focus due to the some- times hazardous nature of weather changes for Southeast. There are no tornadoes, hurricanes, or severe thunderstorms in the weather regime for Southeast Alaska, but WSFO Juneau probably handles more wind storms making landfall with hurricane force winds than any other forecast office in the NWS. WSFO Juneau also has the only NWS Avalanche Forecasting Program in the nation.

II. Purpose

The purpose of this paper is to catalog and briefly describe unique fore-casting problems for the WSFO Juneau area of responsibility. Presentation will be limited to a descriptive discussion of the general meteorological situations which present difficulties in attaining higher levels of fore -cast accuracy.

III. The Upstream Data Void

Perhaps the greatest forecasting problem for Southeast Alaska is the lack of data for analysis for the upstream source regions that dictate the large scale picture for local weather. The dominant source region for the fore- cast area is the Eastern North Pacific Ocean and the Gulf of Alaska. Data received from this area are limited to distant meteorological buoys, ship reports, aircraft reports, GOES and NOAA polar orbiter satellite data. The weather buoys are not in an optimum position to detect weather systems for Southeast Alaska (see Figure 1.) The ship reports are few in number and nearly random in position. GOES satellite data are at the border of useful information in that the view is skewed and the display often cuts off the northern sections of the forecast area.

As can be seen from Figures 2 and 3, the mean storm track is aimed right at Yakutat for the entire year. This situation has profound effect on the weather of Southeast Alaska. If the intensity of each "Gulf Low" was better known, forecasts for Southeast Alaska would definitely improve.

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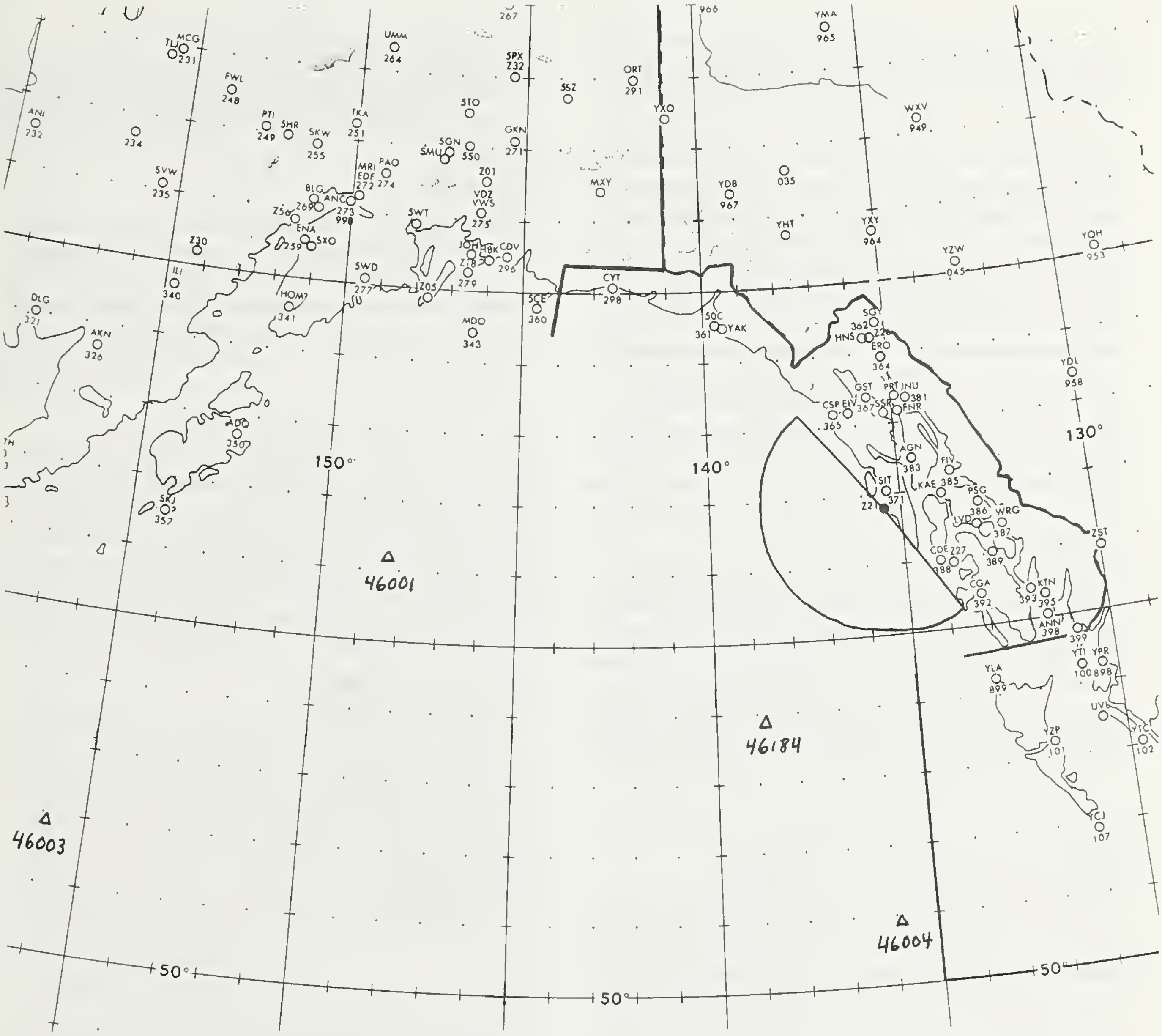


Figure 1. WSFO Juneau Area of Forecast Responsibility

Legend:

1) 3 letter identifiers with open circles - weather observations, some of which have been decommissined.

2) Open triangles - moored weather buoys with bouy numbers.

3) Large semicircle - estimated NEXRAD (WSR-88) coverage at a 10000 foot elevation from Biorka Island near Sitka.

4) Shaded terrain is above 6000 feet elevation.

Inland surface data is also sparse, and many observations are not conducted either on a 24 hour per day or a 365 day per year basis.

The solution to this problem may come under the NWS Modernization and Associated Restructuring (MAR.) A doppler weather radar (NEXRAD - WSR-88) site is planned near Sitak (See Figure 1), and this will have the potential to obtain data out to 200 nautical miles off the coast. This radar will aid in upstream detection. It is unknown, however, as to what benefits NEXRAD will provide in the marine environment. This NEXRAD will certainly not obtain much data onshore due to the terrain. ASOS observations may provide an answer to the temporal gaps in land observations for Southeast Alaska. If the purposed Automated Surface Observing Systems (ASOS) performs as advertised, many more parameters will be available on a 24 hour basis. One worry is that any loss of human observer provided augmentation would be a major detriment to the aviation program or Southeast.

A much better answer to the western data void problem would be to deploy one or two fully equipped meteorological data buoys in strategic locations well offshore. Dectection provided by these buoys would provide a vast improvement in surface analysis and subsequent forecasts. At this time there are no sea state observations in the offshore waters of Southeast Alaska, which is a severe detriment to the sea state forecasts in the marine products.

IV. Wintertime Forecasting Problems

Rain or Snow - Position of the Arctic Front

On a routine daily basis in winter, the most difficult problem is deter- mining precipitation type - rain, snow, rain and snow mixed, or freezing rain. At first glance this would seem to be a typical problem addressed by most forecast offices in winter.

What makes this decision unique for WSFO Juneau is the regularity of proximity of the arctic front and areas of cold air trapped in terrain even when the arctic front has moved well to the north. The proximity of arctic air and maritime air presents quite a temperature and humidity contrast at low levels.

The answer to this forecast problem will be partially solved with an improved data net and an implementation of Nested Grid Model sounding fore- casts (NGM - a primary 3 dimensional model of the atmosphere used by the NWS for shorter term forecasting.) Again, greater density of surface observations on a 24 hour basis would certainly aid in the detection of the arctic front and areas of trapped cold air. If the NGM is preforming well, air-mass prognostication promises to aid the forecasting process by the use of selected "prog soundings" (prognosis) to detect inversion type structure and advection (air movement or replacement) with height. Both of these prospects are exciting as possible solutions to a source of precipitation type and temperature "busts" (missed forecasts).

Taku Winds

A unique problem to the immediate Juneau area is that of "Taku Winds", so named for an inlet and terrain gap that is oriented northeast-southwest near Juneau. Taku winds are possibly the strongest recorded surface winds on earth. An unofficial anemometer on a nearby ridge once broke after pegging at 200 MPH in a fierce Taku wind. Frequently winds of 120 MPH are observed in the town of Douglas across the Gastineau Channel from downtown Juneau.

Taku winds are generated from strong arctic surface high pressure systems centered in Northwestern British Columbia. Research has found that these winds are manifested by an amplified mountain wave causing severe downslope winds. This wind is coincident with occurrence of gap flow through Taku Inlet proper and the Stikine River. Taku Winds are thoroughly discussed in a forthcoming paper by Coleman and Dierking (please see the reference list).

Downslope Drying Effects

A related subject to gap outflow winds and offshore flow in general is the downslope effects on precipitation for many areas in Southeast Alaska. It is well known that in areas of orographic precipitation, a lee side drying effect often occurs. For Southeast Alaska, less precipitation is locally observed for lee side areas under westerly flow aloft; but under westerly flow conditions, dry conditions are rare. As most maritime fronts and low pressure centers approach the coast, a second, more unpredictable downslope drying occurs ahead of the system. East and southeast surface winds often have a significant downslope component. This effect often makes the onset and sometimes even the occurrence of precipitation a difficult forecast, especially for weaker synoptic scale systems. Again, detection through the increased quality and quantity of observations will possibly improve this particular problem.

Rare Maritime Thundershowers

When Pacific fronts move onto the coast of Southeast Alaska, frequently the rain will change to showers along the coast particularly where orographic effects are at a minimum. Inland, orographic effects predominate often causing the continuation of steady rain even after frontal passage. In the Fall and early Winter months, an injection of much colder air associated with trailing upper level disturbances gives a more significant frontal contrast. In these months the ocean surface temperature is very warm relative to the advecting cooler air which is the situation for an unstable airmass to trigger maritime thundershowers. The frequency of

the thundershowers is believed by most forecasters to be rare, however, convective cells frequently appear on the satellite photos in our westward data void. In the weather regime for Southeast Alaska, lightning can be observed from cells with tops as low as 10,000 feet. Satellite loops are an excellent way to detect these cells, and a regional implementation of a new satellite workstation should enhance our forecasting of the maritime thundershowers. NEXRAD will be an excellent diagnostic tool in analysis of which cells are lightning producing CB's (cumulonimbus clouds). The impact of lightning in these sparsely populated is limited to transiting vessels and aircraft.

V. Spring

The transitions from Winter to Spring and Spring to Summer have always presented forecasting problems in northern climates. This transition period can be brief and is usually the time that WSFO Juneau has the most difficulty in forecasting "nice days". As has been previously stated, the dominant maritime and orographic influences yield cloudy skies if not imminent precipitation most of the time. The climatological influence on the forecaster's decision process here in Southeast Alaska is strong. Recognition of the dominate influences is a first step in understanding the weather regime, and the weakening weather systems of the transition period do not help the forecaster pinpoint clement weather in the midst of transitory systems. High pressure inland without arctic strength and temperature makes the task of discerning sunny, mild weather days easier. Southeast Alaska can have stretches of this type of weather for days and even weeks in the spring. The task remains in discerning the one good day that is cherished out of the 15 or 20 days that are inclement. The forecast users seem to be somewhat forgiving in this type of forecasting error.

<u>Fog and Marine Stratus</u>

Fog during the spring months usually occurs during nights with reduced cloud cover after precipitation or from other sources of surface moisture - purely a radiation fog. The problem in forecasting the fog directly corresponds to the problem of forecasting clear skies or even significant breaks in the sky cover against a strong climatology of clouds. Another complicating factor is tideland exposure, due to a tide range of 15 to 25 feet, which can greatly affect the moisture source for radiation fog. Water evaporating and even sublimating from tidelands must by considered in locally predicting fog. An outgoing tide of this magnitude can provide quite a lot of rough surface area from which water can evaporate - adding greatly to the humidity.

Marine stratus occurs under an upper level ridge axis where subsidence caps a marine layer inversion. If the ridge is transitory, the forecast problem is a decision between onshore (advection) or offshore flow (drying downslope effect). In this case detection may be accomplished by purposed ASOS sites giving dew points indicating a marine layer "invasion". Nothing beats having actual cloud observations for the detection of marine stratus advection.

VII. Summer

Routine forecasting for Southeast Alaska in Summer is the greatest challenge for routing forecast accuracy. Weak flow aloft, weak baroclinicity, and the western data void all yield poor forecast model performance for Southeast which is predominant in Summer. The well defined systems of Fall and Winter lend themselves to good extrapolation techniques, but summertime systems yield plenty of surprises with less severity. Marine and aviation activity, particularly with smaller boats and less equipped planes, increases dramatically which makes the forecasts all the more crucial. Details in the forecasts and timing suffers from treacherous weak systems with greater impact. Forecasters are often frustrated with model performance under these conditions.

Remedies, again for this problem, lie in reducing the data void. Detection of upstream weather systems in analysis and knowledge of conditions in a given system would yield improved forecasts. The models are recognized for inaccuracies in the warm season, and the only compensation that a forecaster can make is with better detection.

Marine stratus and fog occur in similar ways as discussed under the Spring section, although occasionally the fog will be advected in from the ocean in summer. Stratus days increase as the summer progresses from July to September with the increase of thermal differences between the interior of northern British Columbia and the cooler marine environment. An increase in onshore flow also increases the occurrence of precipitation in the form of light rain or drizzle. Southeast Alaska can experience a "Marine Push" which is a rapid invasion of marine air replacing relatively dry modified air in summer. The "Marine Push" has been well documented for the Pacific Northwest, and much of the theory readily applies to conditions encountered in Southeast Alaska.

Another summertime condition that affects Southeast a few times each summer is "Back-door" thundershowers. These occur when continental convection is very strong to the east in British Columbia, and a few move across the coastal mountains in easterly flow aloft. These CB's do present a hazard to aviation, and are detected mainly by satellite imagery. Advance notice for this situation is done by an accurate forecast of mid and upper level easterly winds.

VII. Fall

Fall weather for Southeast Alaska can be described for the vast majority of weather situations as two words: rain and wind. During this transitional season, maritime extratropical

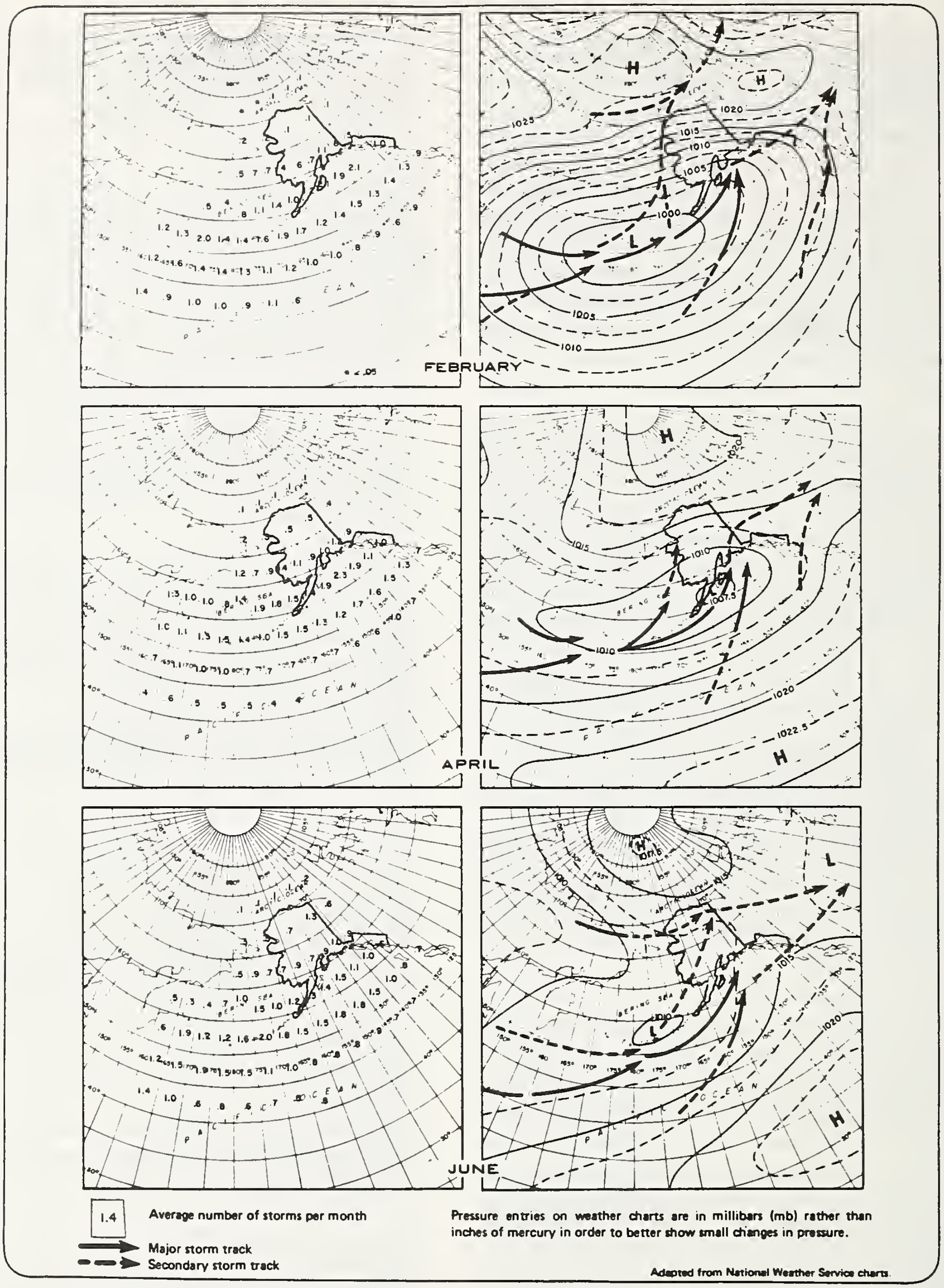
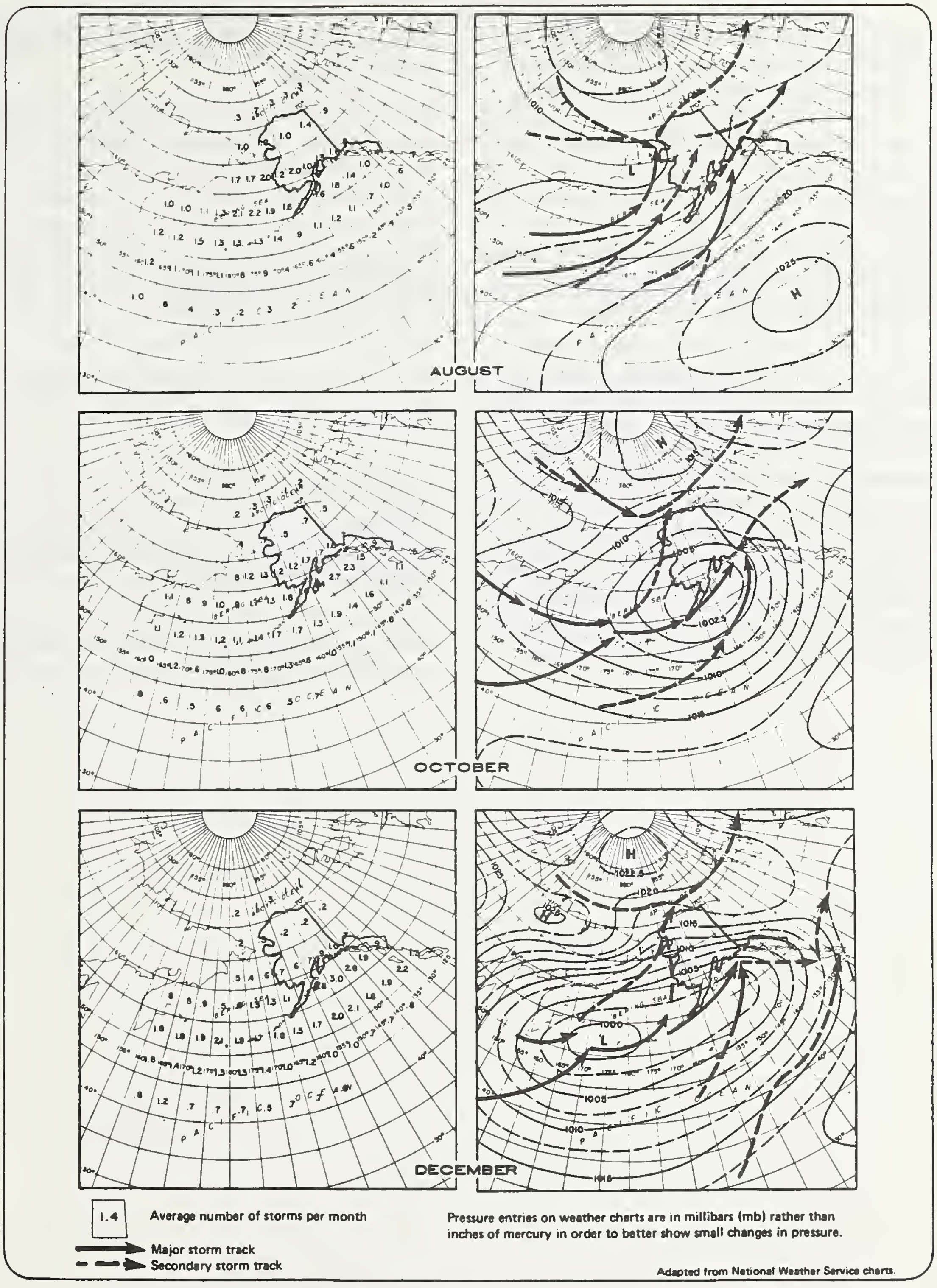


Figure 2. Mean Storm Tracks fro the Months of February, April, and June. (After Alaska Reginal Profiles, 1984)



Mean Storm Tracks for the Months of August, October, December. (After Alaska Reginal Profiles, 1984)

cyclones (large scale low pressure systems) act as the heat transfer mechanisms towards the cooling north latitudes. This sets up a usual average storm track aimed at WSFO Juneau's area of responsibility (see Figures 2 and 3) as previously mentioned. Southeast Alaska will be crossed by deep, mature low centers; series of waves on fronts; and "Bombs" - rapidly deepening lows that meet a criteria of a central falls of a millibar per hour for 24 hours. All of these systems can cause damaging winds and seas. Again, detection by buoys well offshore would go a long way towards improving forecast accuracy regarding these dangerous systems.

With heavy warm sector rainfall in the maritime environment comes the usual hydrologic warnings issued by most WSFO's Juneau, however, does not issue many flood or flash flood warnings because the river basins are sparsely populated and have evolved for rapid runoff. One hydrologic warning that is issued several times per year, particularly in the late fall and winter is for "Local Urban Drainage". This occurs when significant heavy snowfall is followed by heavy rains and consequently causes problems in urban drainage.

Several forecasting problems that have been previously mentioned should also be considered for Fall. These include maritime thundershowers, fog and stratus, and the problem of precipitation type in the borderline rain or snow situation.

VIII. Conclusion

As has been presented above, Southeast Alaska faces a set of unique forecast problems that are based on the combination of physiography and climate. Detection by the deployment of additional meteorological buoys, additional surface observations, and weather radar will enhance forecast accuracy for Southeast Alaska. Improvements under MAR can provide improved forecasting service to public and commercial interests of Southeast Alaska.

ACKNOWLEDGEMENTS

The author wishes to thank the staff at WSFO Juneau for their many contributions to this paper.

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Rainstorm and Flood Damage North Coastal British Columbia 1890-1990

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ABSTRACT:This paper identifies the more important rainstorm and flooding events during the past century. For each such event a brief descriptive history is given, including date, duration, precipitation data, source confirmation, storm details, and other relevant information. The study area is northern coastal British Columbia, including the Queen Charlotte Islands.

This is the first time an effort has been made to compile and summarize all this information.

The dates are derived from climatological and streamflow data supplied by Environment Canada. The information was compiled from as many sources as possible, including newspapers, technical reports, scientific journals, ship logs and diaries. There are major gaps and limitations in the information available. Despite these limitations the paper may serve several purposes. It may give a better understanding about the extent and severity of rainstorms and floods in the area. It may be useful in risk assessment and emergency measures planning. It also may aid in the design and operations of such structures as roads, bridges, railways, pipelines etc. And finally, historians will also be able to get a better understanding about some of the historical events caused by weather that took place in the area.

Predicting Streamflow In Forests During Droughts Due To Changes In Evapotranspiration

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ABSTRACT: A method is derived from the exponetial model for estimating the effect of change in evapotranspiration upon baseflow. Baseflow for Staney Creek, Alaska, was fitted to the model with a recession constant K = 0.9130. An evapotranspiration rate increase of 0,0512 area-cms for 28 percent of the drainage in advanced second growth forest decreased the recession constant to K = 0.8077. The model predicts the reduction of baseflow for a change in evapotranspiration and fraction of forest in second growth regeneration. Partial verification of the model for long term decrease in baseflow is possible from field observations of short term flow increases following logging

Stream Discharge Related to Basin Geometry and Geology, Before and After Logging

Louis R. Bartos

ABSTRACT: Utilizing available U.S.G.S. hydrologic data on five watersheds in SE Alaska with different intensities of logging and two watersheds for a no harvest control; a composite analysis was done to determine the degree of hydrologic change caused by harvesting. The possible controlling basin parameters effecting a streams regimen, i.e., water yield, peak flood flows and mean seven day low flows other than drainage area and amount of timber harvest are geologic makeup, mean basin side slope gradient and basin shape. When considering these basin parameters (excepting basin shape) on floods before and after timber harvest, it was found that in all cases they were significant in S.E. Alaska.

Introduction

There are many parameters that play a part in the interception, collection and transmission of precipitation and determine the extent of discharge and or yield of a forested watershed in Southeast Alaska. The routing processes of water in a watershed are complex because of the many interactions and complex variables as climate, vegetation, sub-surface conditions, basin geometry and its multitude of variables. The quasi-equilibrium of a watersheds natural rhythms are broken by man's influence on the land, in the form of road building and timber harvest. But to what degree of change is it? The knowledge base of watersheds and their regimen 1 and the relationship to forest practices in coastal Alaska is equivalent to producing gold by alchemy. Because of past and present forest practices, there continues to be concern about their effect on the different flows in and from a forested watershed, along with the effect on habitat, spawning, and survival of salmonoid species. The knowledge base of low-flow effects related to timber harvest in Southeast Alaska is still very limited. There has been much concern and research compiled on timber harvest and its effect on watershed hydrology, especially discharge peak, low flows, and yield (Chang et al., 1975; Harr et al. 1969; Harr, 1980; Harris, 1973; Meehan et al., 1969; Rice, 1981; Rothacher, 1973).

Regimen of a stream: The system or order characteristic of a stream; in other words, its habits with respect to velocity and volume, form of and changes in channel, capacity to transport sediment, and amount of material supplied for transportation. Regimen of a stream is also applied to a stream which has reached an equilibrium between corrosion and deposition, in other words a graded stream. Rechard and McQuisten 1968.

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Within this literature are pros and cons regarding timber harvest and its effects on increasing water yield however most of this work has been done in the "lower 48". (Water yield is the quantity of water expressed as a continuous rate of surface flow passing a point in a watershed) This is expressed as volume per unit time (acre-feet per year). Little work has been done to factor that discharge into its individual components.

Until the analysis of Staney Creek discharge data by Bartos, 1989, there was no definitive proof that timber harvest affected low flows in southeast Alaska. At Staney Creek, low flows substantially increased following timber harvest. This data leads one to question: Is this phenomenon uniform over Prince of Wales Island and how does this relate to the rest of southeast Alaska? The one physical parameter that appears to have the greatest effect on the regimen of a watershed is the underlain geology, Bartos,1990.

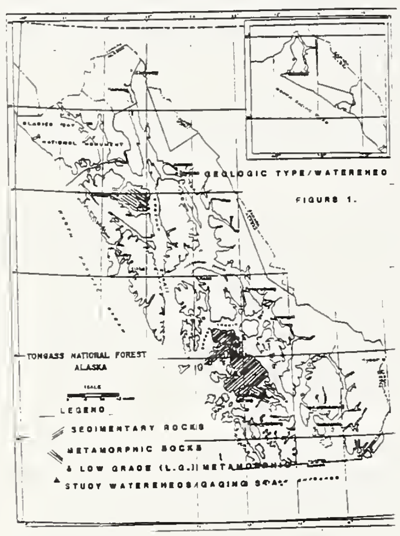
It is rational that the geology and geomorphology in a watershed determine the physiographic or topographic nature of the drainage (shape, relief, channel gradients, and basin side slopes). It is important to recognize that shape and gradient of the drainage are products of the geologic and geomorphic processes and these influence the time distribution of the runoff. Little is known of the relationship between the geology and vegetative manipulation, such as logging, on summer low flows or flood discharge in S.E. Alaska. The second parameter closely related to the geology and geomorphology of the watershed is basin mean slope, since this relates to the rate water passes through the watershed and the amount of basin retention. This leads one to modify their question to: Is there a relation between geology and mean basin slope and annual yield, peak flood flows and the seven day mean low flows.

Discussion

In analysis similar to the one discussed in this paper, stream gages installed a sufficient number of years before timber harvest commenced; and collecting sufficient data collected during

and after harvest. This is possibly the most difficult criteria for any hydrologic evaluation related to timber harvesting in southeast Alaska. There were at least five watersheds in Southeast that barely met the criteria. They included: Harris River, located on the east-central part of Prince of Wales Island, west of Ketchikan, Alaska; Maybeso Creek, an adjacent watershed north of Harris River; Big Creek, on the north-east part of Prince of Wales Island at Whale Pass; Staney Creek in the west-central part of Prince of Wales Island, north of Craig, Alaska; and Pavlof River, located on the north-east side of Chichagof Island, just north of Tenakee Springs, Alaska,

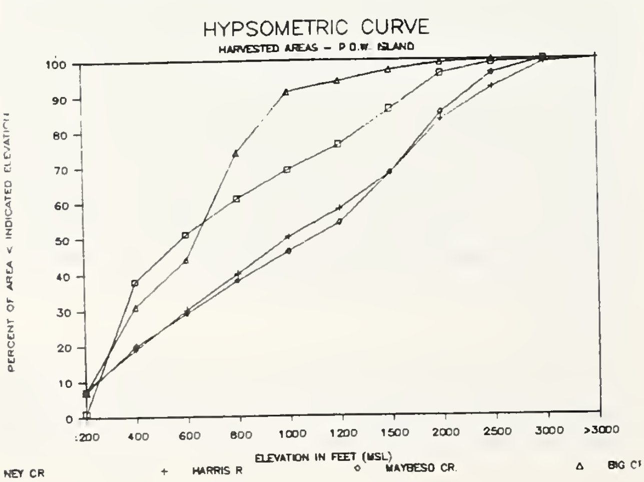
Figure 1: Map showing location of Study



Watershed Characteristics

It has been shown that the geologic makeup of the watershed has a significant effect on the discharge of low flows, Bartos, 1990. As discussed, this is not the sole contributor to the dynamics of a watershed. The primary factor effecting phreatic water, other than the porosity of the soil, is the watersheds side-slope gradient, in this case mean slope of the drainage.

The first step in this process was to develop a hypsometric curve (area-elevation curve) of the four harvested watersheds illustrated below:



The hypsometric curve indicates the evolutionary state of the watershed, and mean elevation, but can also be used for comparing the physical features of the watershed. The curves indicate the watersheds, Harris and Maybeso are in a quasi - equilibrium state of development; where as, Big and Staney Creeks are in a more advanced state of development. This difference is because of the dominant limestone geology in the watersheds of Big and Staney Creeks, limestone more easily eroded and/or dissolved.

The next step is to calculate the watershed mean side slopes, this was done by the equation

$$S=DL/A$$

Where

D= contour interval

L= contour length

A= watershed area

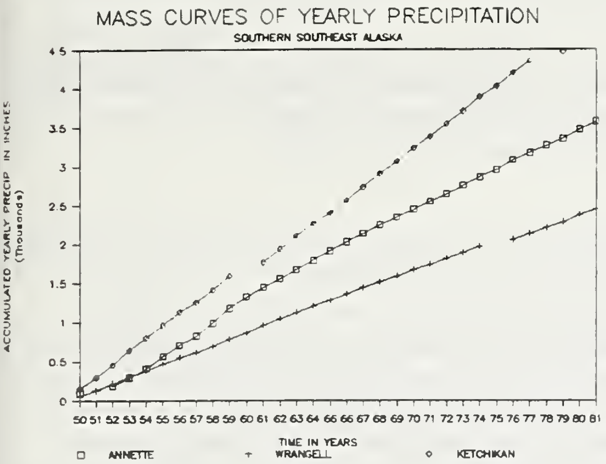
S=watershed mean side slope

There are mean side slopes for metamorphic rocks in Harris River and Maybeso Creek of 34% and 24% respectively. In addition, the sedimentary rock watersheds of Staney Creek and Big Creek have mean side slopes of 24% and 18%.

In this case, there is a significant difference between the watersheds composed of meta-sediments (metamorphic rocks), Harris-Maybeso and the areas containing the limestones sedimentary rocks, Staney-Big Creeks.

Precipitation.

The principal limitations in applying precipitation data in southeast Alaska include location of the recording stations, possible error of the gage, site and recording and the extent of the network in relation to the watersheds being analyzed. Because of the physiographic effects on storms cells moving through the area, localized variation is significant. Particularly, small weak storms with a relative orientation to the land mass, can produce a localized high intensity short duration event. These storm events typically go un-noticed by any existing recording station. This is also the case regarding annual precipitation. An example of annual precipitation limitation lies in the Ketchikan, recording station, where moist cells of air are constricted and up lifted by the significant orographic effect of the adjacent mountains that rise to 3000 fmsl. These conditions produce a mean annual rainfall of 165 inches with extremes recorded over 200 inches, while 12 miles northeast on Guard Island the mean annual precipitation is 65.69 inches. This limitation is shown in an example relating Annette Island weather station to that of Ketchikan and Wrangell, by massing the annual precipitation of each station over time.



It can be seen that there was a rapid increase in annual precipitation for the Annette Island station beginning in 1953 to 1958. This change is attributed to a location change of the precipitation gage to a site closer to the building of the air field complex. This gage could have experienced wind patterns that could have been enough to effect the amount of catch in the gage even with an Alter shield. Wind has a significant effect on the efficiency and accuracy of gage catchment, (Wilson 1954, Bruce and Potter 1957), and for this reason small changes in gage location even if the gage is shielded, can produce gage data errors. When the mean annual precipitation was correlated with annual water yield from the two control watersheds, Old Tom Creek and Indian Creek, there was no relationship. When peak storm precipitation data was related to floods of those particular watershed the relationship was the same. It is concluded that the existing precipitation weather records are of little value for hydrometeorological evaluations related to Prince of Wales Island and that for valid relationships in-watershed precipitation stations must be used.

Table 1. Watershed Characteristics

Name	D.Area	geology	% harvest
Harris River	28.7SM	LG.Met	18.5
Maybeso Cr.	15.1	LG.Met	29.0
Big Cr.	11.2	Sed.	85.0
Staney Cr.	51.6	Sed.	35.0
Pavlof River	24.3	Lg.Met	9.0

Flood Analysis

In many parts of the world, the level of timber harvest in a watershed has a significant effect on its peak flows. The greater the removal of the forest or vegetative cover, the greater the impact of severe flooding.

For each gaging station, the partial peak flood flows were separated between pre- and post-logging (low flows were similarly analyzed in, Bartos, 1989 and Bartos, 1990). The partial peak flow recurrence intervals of each data set were analyzed using the Log Pearson Type III analysis method. From the pre- and post-logging recurrence intervals from each gaging station, the ratios of the 2 and 25-year low flows (2/25 year) were determined.

Basically, the flood ratios of the pre- and post - harvest data for each of the gaged watersheds, with the addition of Pavlof River on the north - east side of Chichagof Island, were calculated and tabulated (Table-2). The principle of this analysis method is that the lesser the quotient, or slope of the ratio of the 2 and 25 year peak flows the greater the increase flood discharge in the basin. These flood increases or decreases can be attributed, as previous stated, possibly to timber harvest or vegetative modification.

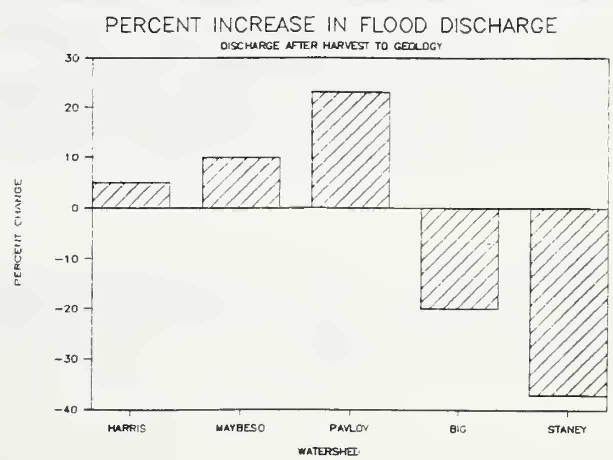
Table 2: Flood Ratios

Drainage.name	Pre-Harvest 2yr/25yr ratio	Post-Harvest 2yr/25yr ratio	-	Percent Difference	Change < >
Harris River	0.45	0.43	+2	5	>
Maybeso River	0.57	0.52	+5	10	>
Big Creek	0.56	0.70	-14	20	<
Staney Creek	0.46	0.73	-27	37	<
Pavlof River	0.58	0.47	+11	23	>

Ratios: > = Decrease in major floods

< = Increase in major floods

Graphically table 2., can be shown as a bar graph representing the percentage of increase or decrease by watershed, graph 3



As can be seen in table 2, the peak flows tend to have a slight increase after timber harvest, in watersheds that have a geology predominantly composed of metamorphics and metasediments based on the existing data. In the watersheds containing a large percentage of limestones, as Big and Staney Creeks, there tends to be a significant decrease in floods discharge

It is thought by some that the Pavlof River analysis shows a significant anomaly since the gaging station is located near the mouth of a 0.15 square mile lake, 0.6 percent of the watershed area. With a small percentage of timber harvest, associated with the minimal routing function of the lake, should not have shown a substantial increase in flood volume. The contribution of the lake is minimal and would have little effect on the suppression of any floods.

There are other factors that also regulate floods and flood magnitude in a watershed and should be investigated as the next step in defining the mechanisms of discharge related to harvest activities in southeast Alaska. Factors identified as most significant include: Snow - The residual volume of snow water on the watershed. Rain on snow - Determine whether or not the event was a rain on snow event. Seasonal Variation - Determine the frequency of flood events by season and their magnitude. Long term climatic changes related to events - Develop a more definitive analysis of climatic changes and variation if any Geometry of watersheds - Determine the most significant geometric parameters of watersheds related to geology. Definitive hydrograph analysis related to floods and low flows.

Many of these factors will be very difficult to obtain because of the poor quality and insufficient data base available at present.

Since the initial analysis of flows from limestone regions of southeast Alaska, an investigation is being conducted by the Forest Geologist and Alaskan speleologist on the extent of caves on north Prince of Wales Island. From preliminary information the author surmises that because of the extent of subsurface cavities, a significant retention of flow is possible. The roll of the subsurface cavities in the flow analysis before and after harvest flood peaks is now unknown.

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INFLUENCE OF ROADS ON WETLAND VEGETATION IN SOUTHEAST ALASKA

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ABSTRACT: The Tongass is the largest National Forest (over 17 million acres) in the United States and encompasses most of southeast Alaska. Approximately, 1.6% of the land is classified as forested wetlands; 9.5% peatland, 3.7% scrub wetlands; 2.3% lacustrine wetlands; 0.2% esturine wetlands; and 42,429 miles of riverine wetlands for a total of over 4.7 million acres. Road building has been a major activity since the early 1950's. Over 2,600 miles of forest roads currently exist on the Tongass N.F. It's expected that this mileage will double over the next 50 years. Most of these roads are built by overlaying pit-run rock on organic soils generally on gentle to flat topography. Because of the high rainfall, much of this flat topography is dominated by wetland vegetation. Consequently, a large percentage of the roads have been built on peatland and forest wetlands and to a lesser extent estuarine wetlands. Vegetation response to this development is highly variable in both direction and rate depending on the how the hydrologic function was disrupted. Previously wet areas have become dryer and are progressing towards forest conditions as indicated by increased tree growth and regeneration. Conversely, wet areas have become wetter and shifts are seen from Sphagnum and short sedge dominated peatlands with highly stagnant water towards tall sedge fresh water marsh communities. In alluvial riparian forests, where terrace building and degradation is an active process, roads have caused some sites to become more stable and other sites to degenerate to alder or gravel bar conditions. Roads built in estuaries which have reduced the extent of saltwater inundation have caused formally grass dominated communities to become forested. The importance of considering changes in hydrologic function and subsequent shifts in resource production in road management planning is emphasized. Opportunities to utilize these concepts in road management planning and restoration are discussed.

SHORT-TERM INFLUENCE OF NATURAL LANDSLIDE-DAMS ON THE STRUCTURE OF LOW-GRADIENT CHANNELS: AN EXTENDED ABSTRACT

Douglas N. Swanston and Robert Erhardt

ABSTRACT: Landslides, one of the principal processes of sediment and large woody debris transport from uplands to anadromous fish streams in southeast Alaska, tend to enter low-gradient channels at nearly right angles. Rapid deceleration from impact of debris with the opposing bank, coupled with a substantial reduction in gradient, causes dewatering and deposition of a debris wedge at and immediately downstream from the point of entry of the landslide. The persistence of the wedge, both as a dam and temporary base-level for the channel, is largely determined by composition of material and the size of flows carried by the channel during storms. Subsequent flows over and around the deposit tend to be sediment poor and energy rich, resulting in more rapid downcutting, increases in downstream channel scour, and the frequent shifting of the channel bed for several hundred meters downstream. In this dynamic environment, the large woody debris piles downstream of the wedge serve as focal points for formation and persistence of habitat elements such as pools, riffles, and side channels. These habitat elements remain viable until occurrence of additional landslides or flood flows with power great enough to remobilize the debris.

INTRODUCTION

Soil mass movements or landslides, a common occurrence in southeast Alaska, are an important source of sediment and woody debris delivered to streams. Such materials strongly influence the morphology of the channel and provide the basic elements for constructing a viable fish habitat. Recent investigations (Swanston and Marion, 1991), suggest that only a small percentage of landslides (generally less then 10%) actually reach the riparian zone and associated channel directly. In these broad, U-shaped glacial valleys, this is primarily due to rapid deposition of landslide debris at the base of the slope where gradients are drastically reduced and to distance from an active channel. For the most part, channels that are directly impacted by landslides tend to be in narrow, confined 2nd- and 3rd-order drainages, or in higher order drainages located adjacent to cliffs or unstable slopes. When landslides do reach the channel, velocities tend to be high, the total mass of soil, rock, and organic debris is large, and the physical impact of the landslide mass and entrained debris can produce major changes in channel characteristics and stability downstream of the point of impact.

DOMINANT LANDSLIDE PROCESSES

These landslides range from simple bedrock slides and topples involving the collapse of rock cliffs due to hydrostatic pressure and freezing of water in joints and fractures to complex debris flows and debris torrents triggered by excess pore-water pressures generated during high-intensity storms .

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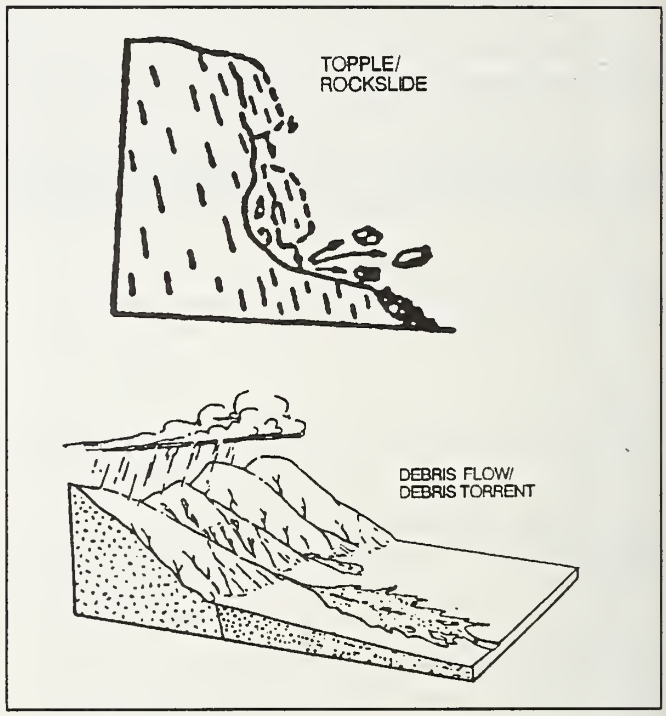

Figure 1. Principal processes responsible for landslide dam formation in southeast Alaska. (Top) Topple/rockslide; (bottom) debris flows/debris torrents.

Topples and rockslides account for only a few of the total landslides reaching the riparian zone. These are very rapid, planar failures of bedrock along joints and fractures in cliffs and steeply dipping rock slopes. Water may be present but is not a primary mobilizing element in transport of materials. Almost all the material, a mixture of soil and woody debris

dominated by large, coherent blocks of rock, is carried to the valley floor or adjacent stream channel by free-fall, rolling, and bounding. Debris flows constitute the most common and damaging of these landslides in the region (Swanston, 1974).

Debris flows are rapid, planar, water-charged mass movements that develop on steep hillslopes and generally contribute 60% or more of their initial failure volume almost immediately to the base of the slope or intersecting channel. Areas prone to debris flows are typified by shallow, low cohesion soils and steep slopes where subsurface water is concentrated in subtle, soil-filled linear depressions above impermeable bedrock or glacial till surfaces.

Debris torrents or debris floods are a special case of debris flow, where water-charged soil, rock and organic debris moves rapidly through confined channel systems. These events are triggered during extreme stormflows by (1) debris avalanches and flows from adjacent hillslopes, which enter a flooded channel, are incorporated into the main flow, and move directly downstream; or (2) by breakup and mobilization of debris dams and major debris accumulations in the channel. The initial slurry of water and associated debris commonly entrains large quantities of additional inorganic and living and dead organic material from the streambed and banks. As the torrent moves downstream, hundreds of meters of channel may be scoured to bedrock. When the torrent loses momentum, a tangled mass of large organic debris is deposited in a matrix of sediment and fine organic material covering areas up to several hectares (about five acres) (Swanston and Swanson, 1976).

SPEED OF MOVEMENT

The speed of movement of these processes is variable and depends on initiating mechanism, slope gradient, and water content.

Topples occur at speeds generally greater then 8 meters/second (18 miles/hr), involving free-fall and rolling, sliding, and bounding of large blocks along very short, steep slope sections. Water may or may not be involved in initial movement.

Debris flows generally occur at speeds of 1 to 3 meters/second (2-7 miles/hr, moderate to fast walking speeds), with speed increasing with slope gradient and water content.

Debris flows on very steep slopes (gradient greater then 34 degrees [67%]) with high water content, and debris torrents or debris floods in confined channels, frequently exceed 5 meters/second (11 mile/hr.) and have been reported as high as 16 meters/second (36 miles/hr.) (Curry, 1966).
Speed rapidly decreases with reducing gradient and loss of confinement as material becomes lodged along the flow path and internal friction of the spreading flow mass increases. On slopes below about 16 degrees (26%), rapid deposition generally occurs and most of the entrained soil, rock and debris is deposited within 100-200 meters (328-656 feet) of the point of initial deposition.

CONTROLLING TERRAIN CHARACTERISTICS

Channel disturbance by topples and rockslides is determined primarily by the adjacent location of exposed rock bluffs and cliffs with structural elements (joints and fractures) open to the inflow of surface and subsurface water. The resulting freeze-and-thaw activity, or the hydrostatic effects of accumulating water in the joints and fractures during storms pry loose large rock units which slide and roll down slope incorporating overburden soils and forest vegetation.

Recent work in the Oregon Coast Range (Benda, 1985a,b) suggests that deposition and length of channel disturbance by debris flow and debris torrent processes can be correlated with basin area, junction angle of a debris flow with the stream channel, channel gradient, and magnitude of stream discharge encountered at the time of debris flow entry. Debris flows that enter a 2nd- or 3rd-order channel at acute angles of less then 45 degrees tend to be incorporated directly into the channel flow as a debris torrent and may extend downstream for more then 300 meters (984 feet) before appreciable deposition of sediment and organic debris occurs. Debris flows that enter 2nd- or 3rd- order channels at nearly right angles (70 to 90 degrees) immediately encounter decreased channel gradient, increased channel widths and abrupt changes in flow direction. These factors all force rapid deposition of transported materials at or near their point of entry.

The size of these flows and the extent of damage produced also appears to be controlled by drainage area. In basins of small drainage area, there is a potential for deposits to dominate the morphology and control stability of the channel for long periods. With increasing drainage area, discharge is higher and deposits tend to breach during placement or soon after, resulting in more rapid and frequent destabilization of the channel system.

LANDSLIDE DAM FORMATION

In southeast Alaska, both topples and debris flows tend to enter low-gradient channels at nearly right angles. As a result, rapid deceleration from impact of debris with the opposing bank, coupled with a substantial reduction in gradient at the point of entry, causes dewatering and deposition of a debris wedge with its greatest volume immediately downstream from the initial point of entry of the landslide. In narrow or confined valleys, there is frequently a variable zone of disturbance or "blast-zone" opposite the wedge, where trees are knocked down and lie at various angles in relation to the

direction of impact. This zone is a product of the sloshing action of water charged debris as it strikes the opposing bank. These debris wedges serve as a dam causing ponding, sediment deposition, and riffle formation upstream and at least a temporary barrier to fish passage. They also serve as a temporary base-level for the channel, increasing gradient for a variable distance downstream and resulting in destabilization and reactivation of channel migration, scouring, and bar formation. The persistence of the wedge, both as a dam and temporary base-level for the channel, is largely determined by composition and size of material and the size of flows carried by the channel during storms.

CHANNEL DISTURBANCE

The most persistent type of landslide dam is caused by topples and rockslides. The large rocks that are the major component of this type of obstruction remain in place for many years before they are cut through or by passed. A good example of this type is illustrated at Robinson Creek in Misty Fiords National Monument (figure 2).

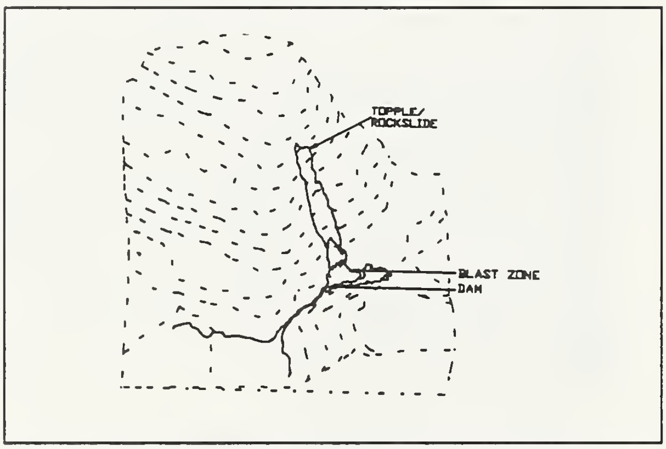

Figure 2.: Perspective view of lower Robinson Creek, Misty Fiords National Monument showing topple/rockslide, dam and blast zone, ca. 1989.

The dam was formed during a fall storm in 1986 by a topple from the left or northern slope of the valley where it encroaches upon and forms a prominent cliff above the creek. The entire channel was blocked forming a stepped falls and a complete barrier to fish passage to the upper reaches of the creek. Cross-sections established in 1987 across and below the dam have indicated no significant changes to the dam and channel downstream over the past four years. Fish are still blocked from passage to the upper channel and no detectable down-cutting of the channel across the dam has occurred. The channel downstream of the dam has remained relatively stable despite increased flow energy because it is largely floored by bedrock. There is little new large woody debris in the channel below the dam and little new large woody debris on the beach beyond the mouth of the creek, suggesting that most of the organic material carried into the creek by the topple remains incorporated in the dam.

The more common debris wedge is generated by debris flows and consists of a mixture of fine to coarse sediment, and large woody debris. A substantial amount of the large woody debris carried by the initial flow tends to float on the top and along the lateral margins. As deposition of the wedge begins, much of this material is carried downstream and deposited within and along the margins of the channel as individual logs and stumps and as piles of large woody debris. These individual pieces and piles form local channel obstructions that cause channel shifting and function as the loci of scour pools and bar construction. These structures remain viable until occurrence of additional landslides or flood flows with power sufficient to remove them. Because the materials deposited in this type of wedge are easily erodible, downcutting begins almost immediately and the wedges remain as significant obstructions for only a few years before they are incised or bypassed. Evidence of these by passed wedge deposits are widespread in the coastal valleys of southeast Alaska; they are identified by tight meanders in the stream channel toward the opposite bank and collapsed cones of sediment and woody debris around which the stream now flows.

Despite the limited persistence of this type of wedge, such obstructions have a significant destabilizing effect on the channel downstream. Subsequent flows over and around the deposit tend to be sediment-poor and energy-rich, resulting in increased downcutting, channel scour, and frequent shifting of the channel bed for several hundred meters downstream. Scouring and channel shifts are particularly common. At Weasel Cove in Misty Fiords National Monument (figure 3), a dam was created by a 1986 debris flow that occurred during the same fall storm that impacted Robinson Creek.

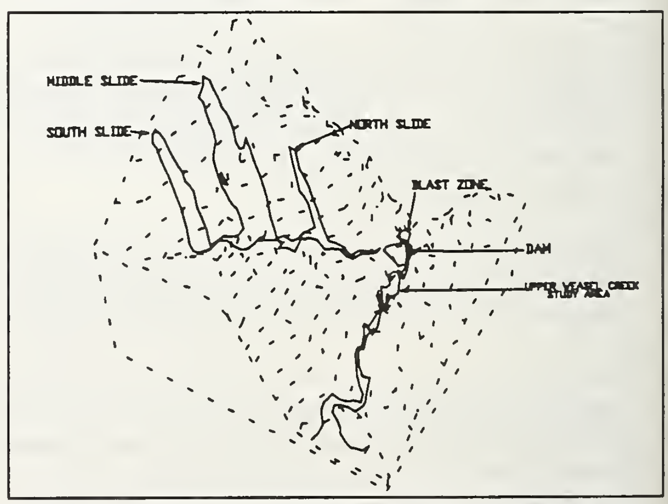

Figure 3: Perspective view of lower Weasel Creek, Misty Fiords National Monument showing debris flows, dam and blast zone, ca.1989.

This dam was breached almost immediately and has not caused a significant barrier to fish passage. The wedge still remains as a partial obstruction, however, and the channel remains dynamically unstable downstream.

Profiles constructed from annual surveys of about 60 cross-sections (Figure 4) indicate that the main channel has migrated annually, and over the last four years, has moved completely across the valley floor.

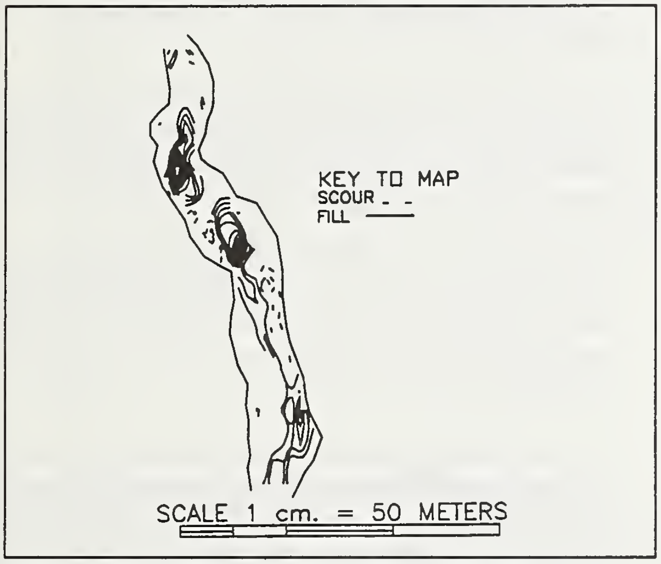

Figure 4. Map of 1989 and 1990 channel changes and ccour-fill activity during winter of 1989 in lower Weasel Creek below landslide dam. Channel is shifting westward with large-scale downstream movement of pools and riffles.

Active scouring is continuing to occur immediately downstream of the dam and at the upstream side of several large woody debris piles. Plots of the change in volume of scour and fill areas in this section of the channel indicate continuing downstream shifts of pools and riffles with a net increase in bar development of 50 cubic meters/year (1765 cubic feet/yr).

Similar dynamic destabilization is being monitored in two tributaries of Saginaw Creek, on the northwest end of Kuiu Island. These tributaries were heavily impacted by debris flows generated during a major rain on snow event on November 30, 1988. Both debris flows began as shallow debris avalanches from canyon side-slopes, entered the canyon at near-right angles, and temporarily dammed the channels to produce major torrent or flood flows downstream. On the southern-most tributary, the sediment wedge remains in place, but has been partially bypassed. The initial sediment wedge in the northern tributary has been completely removed by subsequent flows. The resulting torrent flows in the lower tributaries deposited their sediment and large woody debris loads just short of Saginaw Creek due to rapid gradient reductions and the buttressing effect of intervening second-growth timber.

In 1989, a series of cross-sections were established to document the changes to the channel after the slides. Initial comparisons after the 1990 surveys (Figure 5) show that in the southern tributary, major destabilization of the channel persists and a large amount of material is being transported through the intermediate channel system below the sediment wedge and above the low-gradient deposition zone.

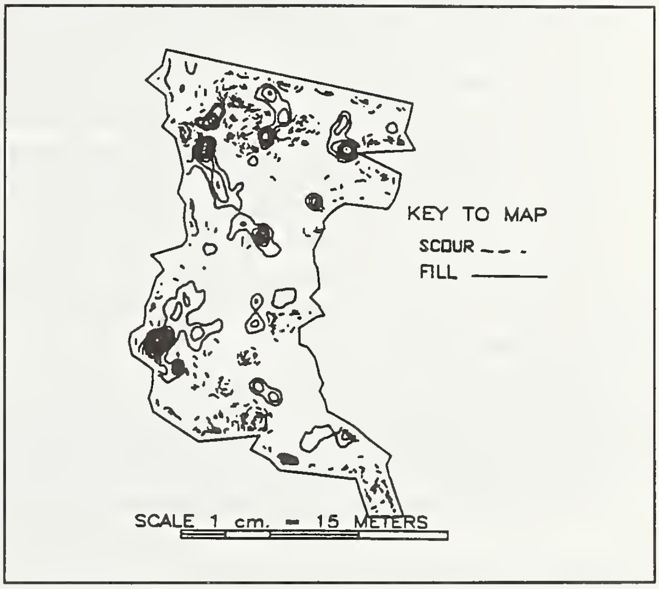

Figure 5. Map of 1989 and 1990 channel changes and scour-fill activity during winter of 1989 along the path of the South torrent of Saginaw Creek, Kuiu Island. Channel is rapidly degrading, with formation of pools above the debris wedges below buried rocks and logs.

This material is being deposited in a developing fan adjacent to Saginaw Creek, producing a rapidly shifting main channel in the deposition zone. In just one year, over 2900 cubic meters of material has been transported through a 200-meter reach of the active scour zone. Large woody debris transported by the initial torrent flows in these tributaries is primarily lodged in large piles adjacent to flood-flow boundaries well above the active channel or at the lower end of the deposition fan adjacent to Saginaw Creek. Except for woody debris that may have entered Saginaw Creek, this material has had little effect on current channel dynamics. The continuing scour and channel shifting is largely the effect of increased stream energy and the variable resistance to erosion of rocks and buried logs being excavated in the channel bed. These have produced local sediment wedges above and scour pools below sharp bends in the newly forming channel.

CONCLUSIONS

It is clear from our continuing studies, that topples and debris flows entering 2nd- and 3rd-order channels at nearly right angles are an important element in the formation and modification of channel morphology in low-gradient channels in southeast Alaska. The resulting dams and associated sediment wedges generally persist for at least five years either as a complete barrier or a partial obstruction to fish passage, and cause substantial destabilization of downstream channel segments. Once such obstructions are initially in place, sediment and organic debris from upstream become trapped. Subsequent flows over and around the deposit tend to be sediment poor and energy rich, resulting in more rapid downcutting, increases in downstream channel scour, and the frequent shifting of the channel bed for several hundred meters downstream. In this dynamic environment, the large woody debris piles downstream of the wedge serve as focal points for formation and persistence of habitat elements such as pools, riffles, and side channels. These habitat elements remain viable until occurrence of additional landslides or flood flows with power great enough to remobilize the debris.

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Physical Characteristics of Beaver Dams and Pond In Southeast Alaska

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ABSTRACT. The physical dimensions of 45 beaver dams and ponds on the north portion of Kuiu Island in Southeast Alaska were measured to determine the hydrologic effects ponds have on storm peak flows. Physical dimensions were needed to calculate dam stage-discharge and pond stage-storage relationships. The average dam length and height were 32 m and 0.7 m, respectively. The average pond length was 61 m for both summer- and winter-stages. Beaver ponds had an average summer-stage surface area and volume of 1,020 M2and 1,700 m3, respectively. The winter-stage pond surface area and volume averaged 2,140 m2 and 1250 M3, respectively. Routing of peak flows through beaver dams and ponds using the Modified Puls method did not greatly affect peak flows. Flat dam profiles of beaver dam are probably the principal factor for the limited effect on peak flows.

Introduction

The presence of beavers (Caster canadensis) may be an important factor affecting the hydrology and physical characteristics of mountain streams. Beavers are one of the few animals that can greatly alter the environment in which they reside. Beaver dams and ponds can flood adjacent riparian areas, raise groundwater levels, and create wetland habitats. Stream changes resulting for beaver occupancy generally enhance fisheries habitat and improve water quality.

Several authors have suggested that beaver dams and ponds reduce storm peak flows (Scheffer, 1938; Retzer, Swope, Remington, and Rutherford, 1956; Neff, 1957; Allred, 1980, and Parker, et al., 1895), however no data exists to support this claim. The objective of this study was to: (1) determining the physical dimensions of beaver dams and ponds and (2) use the dimensional information with an appropriate flow route model to determine the hydrologic affect of dams and ponds on storm peak flows.

Methods

Beaver dam and pond field measurements were conducted in the northern portion of Kuiu Island. Dam and pond sites were randomly selected to encompass the full range of dam and pond types associated with various watershed settings. Along with dimensional evaluation, watershed physical features that assisted in the characterization of terrain types associated with dams and ponds were measured. The watershed features measured include valley width, local stream gradient, stream cross-sectional area, and stream standing water volumes.

Dam anchors represent large structural elements that are used by beavers to reinforce or aid in holding a dam in place. Anchors generally consist of large woody material (e.g., down logs and standing dead or living trees.) Measurements of down logs consisted of length and large end diameter. Diameter at breast height (DBH) and species were also recorded for standing trees.

For each beaver dam, the length, height, and base width were measured. Dam length was determined by positioning a tape along the top contour between the detectable ends of the dam. Dam height was defined as the elevation difference between the top of dam and the immediate downstream area not disturbed by beaver activities. In areas where a downstream pond occurred along the dam, it was used to define the base of the dam. This measurement protocol maintained consistency in areas that may have disturbed by beaver activities. The elevation difference between the top of the dam and the pond surface was also measured to determine the longitudinal profile of the dam for weir calculations.

Pond dimensions were determined to calculate storage volumes required for pond routing. Pond length was defined as the linear distance from the top of the dam to the farthest up-valley influence of the pond. Pond depth measurements were obtained at intervals across the pond; location was influenced by the presence of logs, trees, and bottom topography. Depth transects were conducted perpendicular to the longitudinal axis of the pond.

Pond routing was accomplished using the Modified Puls method to determine the reduction in storm peak flows (McCuen, 1989.) The Modified Puls method is an instantaneous

outflow model that uses the basic reservior mass balance equation:

INFLOW + STORAGE = OUTFLOW (1)

This method requires approximately a linear inflow hydrograph between time steps. Stage-discharge relationships were calculated by simulating a series of rectangular broad-crested weirs. The general broad crested weir equation is Q = CLH3/2, where C is the routing coefficient, L is the weir length, and H is the head over the weir. Length and elevation of each weir was based on field measurements that identified elevations along the crest of the dam. The overall stage-discharge relationship for a dam was obtained by summing discharges from each weir. Pond routing simulations were conducted on five storm event return intervals and six watershed sizes using a triangular inflow hydrograph.

Results and discussion

The ability of beavers to utilize available riparian vegetation in dam construction is a trait that is not well understood. One of the possible reasons for the variable longevity of dams may be the durability of dam anchors. Standing trees and down logs were the primary anchor used by beavers on Kuiu Island. The most common standing tree species incorporated into beaver dams were Sitka spruce (41%), Red alder (15%), and Western hemlock (13%). The remaining 31% consisted primarily of dead unidentifiable trees. The DBH for the common tree species were 0.52, 0.39, and 0.19, respectively. The overall DBH for dead or living standing trees incorporated in dams was 0.37 m. Down logs averaged 14.1 m in length, this average log length was 44% of the average dam length. The average large end diameter for down logs was 0.39 m. Recent studies of woody debris in streams suggest that the best stability may occur when log linnets equal or exceed stream bankfull width (Gillilan, 1989.) The average number of standing trees and down logs per dam were three and two, respectively. The total number of anchors per dam was not calculated due to the unknown number of down logs concealed by dams.

Valley shape and size may be important factors determining the general type of beaver dam (i.e., short and high or long and low.) However, establishing the exact relationships are difficult due to the highly variable nature of floodplains and beaver dams. Local floodplain morphology, channel type, and water oveflow pattern appear to be important factors affecting the exact size and shape of beaver dams. The average dam length was 32 m; 55% of the lengths were between 10 and 30 m. A large proportion of the dam lengths extended a substantial distance over the adjacent floodplain. The average dam height was 0.7 m and ranged from 0.5 to 1.5 m. Pond length average 61 m and ranged from 7 to 195 m. Seventy-five percent of the pond lengths were 78 m or less. Pond length is not a reliable measure for determining the extent beavers can influence streams. Generally, beaver ponds in low gradient channels extended to the next upstream dam, hence pond lengths did not change as pond volumes increased. On low gradient streams, the presence of an upstream dam site appeared to limit pond length, rather than the height of the downstream dam.

According to U.S. Forest Service personnel on Kuiu Island, the annual precipitation of Southeast Alaska was about 20 to 30% below normal during the period field data was collected. Streamflows and pond volumes on Kuiu Island was correspondingly low.

Due to the reduced volume of stored water within the ponds, water had to be mathematically added to simulate winter storm condition for pond routing. Pond dimensions present during field sampling are defined as summer-stage. The mathematically "filled" dimensions are fined as winter-stage.

Pond summer-stage surface area and volume averaged 1,020 m2 and 1,700 m3, respectively. The average winter-stage pond surface area and volume were 2,140 m2 and 1,250 m3, respectively

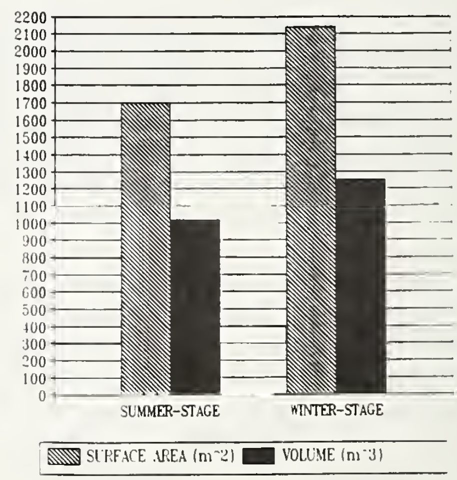

Figure 1. Summer- and winter - storage average pond volumes and surface areas on Kuiu Island, Alaska.

Seventy- five percent of the winter-stage pond volumes were 988 m3 or less. The data indicated that beaver ponds can create a considerable amount of slack water habitat along streams systems that would not normally be present. Beaver ponds may greatly increase the volume of water stored on watershed compared to similar free flowing reaches that do not have beaver ponds. Thus, altering the volume of stored water and hydrograph timing within a watershed may change the hydrologic response at the outlet of the watershed. The summer-

stage ratio of pond volume to channel volume averaged 37 and ranged from 1 to 121.

The basic assumption for many years has been that beaver dams and ponds have a hydrologic effect on peak flows. Reductions in peak flow may occur when inflows are temporarily stored in beaver ponds before being released downstream. Increasing the detention storage for a particular pond, increases the expected reduction in peak flows. Dam and pond dimensional characteristics were used to calculate stage-storage relationships required for pond routing.

Beaver dam crests on Kuiu Island had relatively flat surface profiles. Stage-discharge relationships were developed using one to three rectangular, broad-crested weirs for each beaver dam. A small increase in pond head resulted in a large proportion of the beaver dam functioning as a discharge surface. Consequently, beaver dams routed water very efficiently through the site. This efficiency prevented large volumes of water from being store in the pond during storm events.

A single beaver pond seems to have little affect on storm peak flows .

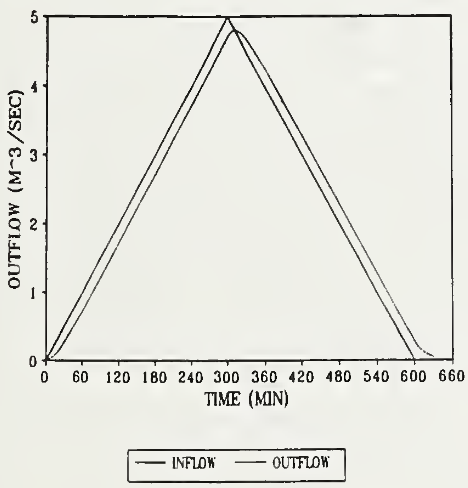

Figure 2. General inflow and outflow hydrographs for a large beaver pond on Kuiu Island, Alaska.

The outflow hydrograph has a slightly lower and broader peak with the total hydrograph duration increased by only few minutes. The magnitude of the reduction depends on the pond and storm size. A larger pond will have a greater effect than a smaller pond, however a larger storm event will result in a lesser affect than a smaller storm. Storm events routed through a series of ponds with no free flowing channel between will have a larger affect on peak flows than a single pond. Peak flow reductions are again dependent on the size of the pond and storm event, plus the number of ponds in series. Beaver dams and ponds may still be hydrologically important. The large discharge surface may route water into the downstream floodplain. Floodplain discharge could have a much greater affect on peak flows than just the dams and ponds alone. The peak flow reduction will depend on the volume of water routed onto the floodplain, distance from the channel, and how efficiently the water is routed to the stream. Beaver dams and ponds are also important in slowing stream velocities, storing sediment, building stream banks, and providing increased fisheries habitat.

Conclusion

Beaver dams and ponds are highly variable components of the landscape that fulfill a wide variety of biologic and hydrologic functions. The potential for peak flow alterations represent only one of these functions. Pond type appears to be determined by valley shape, however, the exact dimensions are determined by local stream and floodplain morphology.

Dam anchors are likely a major contributor to overall dam stability. Increased size and number of anchors should decrease the probability of dams "blowing out" during high flows. Beaver dams on Kuiu Island were generally long with low heights. A large proportion of the dam lengths extended onto adjacent floodplains.

The flat surface profile of beaver dams was probably the principal factor for the small peak flow reductions. The magnitude of reduction is a function of the volume of water stored from the inflow hydrograph. Increasing pond stage resulted in a large proportion of the dam discharging water downstream, preventing the storage of large quantities of water. Without this storage from the inflow hydrograph, there cannot be an affect on the outflow hydrograph. Peak flow reductions are related to antecedent conditions, inflow hydrograph shape, dam and pond size, outlet structure configuration. Although the effects of a single beaver pond upon peak flows in relatively small, a series of beaver ponds could have a greater affect on storm hydrographs than a single pond. Further more, redistributing flows across broad floodplains at the pond outlets may have a much greater affect on peak flow than just the dams and ponds themselves.

Acknowledgments:

The financial and logistical support provided by the U.S. Forest Service and Oregon State University was vital to the completion of this project. Special thanks goes to the Experimental Research Laboratory in Juneau, especially Rick Smith, Kathy Hocker, and Sara Highland. The cooperation of the Petersburg Ranger District (Pete Tennis, Luanne Powers, etc.) was greatly appreciated, data collection could not have occurred without their logistical support.

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Effects of Large Woody Debris on Channel Unit Distribution in Southeast Alaska

Richard D. Smith and John M. Buffington

ABSTRACT: The importance of large woody debris (LWD) in stream channels in forested areas is documented by research conducted over the past several years. As a result, the practice of removing LWD from streams in managed areas has generally been discarded. More information is needed however to refine guidelines, including effective designs for buffer strips for management within riparian zones. Information is also needed to improve guidelines for rehabilitation of streams impacted by outdated management practices. Presumably, the riparian zone must be relied upon to provide the stream channel with a sustained supply of debris necessary for maintenance of channel morphologic characteristics that provide fish habitat. The amounts, sizes, and types of debris required to provide adequate fish habitat are not well known. We are addressing these information needs by conducting studies of the distribution of stream channel units in both undisturbed streams and streams where loading of LWD has been reduced. Channel units are spatial divisions of a stream channel distinguished by local hydraulics and channel morphology and are generally analogous to fish habitat units.

Preliminary results clearly indicate that LWD loading and characteristics are among the most important variables controlling the distribution of channel units, in particular various types of pools.

Previous research has documented the importance of large woody debris (LWD) in stream channels in forested areas (Harmon et al., 1986; Bisson et al., 1987). We now recognize that one important function of the riparian zone is to supply LWD necessary for maintenance of channel morphology that provides fish habitat. The practice of removing LWD from streams important to anadromous fish has generally been discarded in areas managed by the U.S. Forest Service, and management practices in riparian zones are designed to maintain natural recruitment of LWD in streams. Additional information is needed to refine guidelines for management within riparian zones in order to insure sufficient quantities of LWD for long-term maintenance of fish habitat. Information is also needed to improve guidelines for rehabilitation of streams impacted by past management practices. Carefully planned introduction of LWD into stream channels can be an effective method of restoring fish habitat. The amount, size, type, and orientation of debris required to restore degraded stream habitat is not well known. In addition, measurement of the influence of LWD on channel morphology will increase our general understanding of the structure and function of stream ecosystems in forested areas of southeast Alaska. We are addressing these information needs by conducting studies of the distribution and control of stream channel units in both pristine streams and streams where loading of LWD has been greatly reduced by land management or as part of a research experiment. Channel units are spatial divisions of a stream channel distinguished by local hydraulics and morphology and constitute distinct units of fish habitat. These units include riffles, glides, various types of pools, and other unit types (Bisson et al., 1982; Sullivan, 1986). Channel units should not be confused with channel types, which apply to entire sections of a stream commonly composed of hundreds of channel units. The typical disturbed stream we are studying was logged prior to the implementation of current protective management practices. The riparian zone was cut to the stream bank and most or all of the in-channel LWD was removed. This contrast of pristine with greatly disturbed streams is not intended to reflect current practices, rather it allows us to isolate processes associated with LWD. Twenty-four stream reaches in various locations throughout the Tongass National Forest are being studied (Fig. 1). Each study reach is twenty channel widths long. At each site we record channel unit types and dimensions and any obstructions, such as LWD, related to pools. Pools are commonly formed by scour around one or more obstructions. Obstruction type, size, and position within the channel are noted, as well as obstruction and channel unit orientation relative to flow. Long profile surveys, cross sections, and pebbles counts are used to measure channel slope, dimensions, and grain-size characteristics. Objective criteria are used to distinguish channel units. For example, glides, riffles, and cascades are distinguished by local channel slope. Pools are distinguished by depth relative to the active channel edge, scaled by channel width. Pools in both pristine and disturbed channels are associated with an average of two obstructions. Multiple obstructions tend to create complex relationships between pool and obstruction characteristics. One obstruction,

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such as a large log, may influence the development of as many as five distinct pools. In contrast, as many as ten obstructions may affect a single pool. Thus we distinguish obstructions as being either dominant or associated relative to pool formation. Preliminary results indicate that in pristine streams, pools make up 48% of the wetted channel area. Scour pools are the most common type of pool. In shallows (non-pool areas) glides are the most abundant unit. In contrast, pools make up only 28% of disturbed streams, with scour pools again the dominant type of pool. Scour around LWD dominant obstructions creates 80% and 46% of the pool area in pristine and disturbed streams respectively. In pristine streams single pieces or clusters of LWD are by far the most common pool-creating types of obstructions. Single logs, rootwads, and debris clusters are the most important of these. In disturbed channels non-debris obstructions, such as large boulders or resistant bank protrusions, play a greater role; however LWD, such as single logs, stumps, and rootwads, remains the most abundant type of obstruction. In these channels the few old-growth logs and stumps remaining after timber harvest appear to play an important role in forming the larger, deeper, and more stable pools. Preliminary results of this study indicate the importance of LWD in the formation of pools and the complexity of interactions between obstructions and pools. These results also provide a quantitative description of pristine stream habitat conditions that can serve as a guideline for habitat rehabilitation projects. Continuing data collection and analysis will further quantify the amount of LWD necessary to maintain habitat, the relationships between obstructions and pools they create, and the longevity of debris in streams.

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Figure 1. Location of study sites.

A Hierarchial Habitat Unit System for Stream Surveys

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ABSTRACT: Describing stream habitat and its relationship to fish populations often depends upon a subjective interpretation of morphological characteristics of streams. At the pool-riffle level there is usually good agreement, but categories and criteria vary widely among observers and tend to be customized by the individual doing the survey when greater detail is required. This leads to poor comparability among observations and surveys. We developed a three-level hierarchial system comparable to a taxonomic system with families composed of genera that included several species. Macro-, meso-, and micro-habitat classifications are based on the detail of description of the habitat unit rather than on the size of the stream or stream segment. Criteria are based on objective observations of flow --direction and velocity--, channel morphology --gradient and shape--, and water surface turbulence-- smooth or broken. A similar system was developed for cover that included categories of rock and wood cover. The method was used in stream surveys in New Hampshire and in southeast Alaska. Surveys in both regions were accompanied by snorkel counts of salmonid populations. Criteria for habitat units were applied in both geographic locations and similar features appeared to be selected by salmonid populations. The system may be used as a further refinement of the Channel Type Classification System currently used in many stream surveys throughout Alaska.

Inventory on the Coastal Plain (1002 Area) of the Arctic National Wildlife Refuge (ANWR).

John Trawicki

Water Resource Branch

U.S. Fish & Wildlife Service, Anchorage

ABSTRACT: The Water Resource Branch of the U.S. Fish and Wildlife Service has been conducting an extensive water inventory in the 1002 area of the Arctic National Wildlife Refuge (ANWR) since 1988. The intent of the water survey is to develop a hydrologic data base, map potential sources of winter water, and provide water quantity and distribution data to resource specialists and managers.

A survey of ice hummocks was conducted on the major river systems in the 1002 area. A linear relationship between hummock size and free water below the ice was found, but the quantity of water was small (Elliot and Lyons 1990).

An inventory of lakes within the 1002 area was completed in 1990. Results showed that few lakes exceeded seven feet in depth and those that did were congregated in a few small areas. With ice thickness approaching seven feet by mid April, available winter water is drastically reduced (Trawicki and Lyons 1990).

The Water Resource Branch has on going discharge monitoring program. The program began in 1988 and three years of data have been collected to date. The three water years have been significantly different and provide stream discharge data for a variety of conditions.

Water sources of the 1002 area are not similar to those of Pruhdoe Bay. If gas and oil exploration activities are going to occur, alternative sources of water will need to be developed.

CYANIDE: A Review of Literature on the Toxicity of Cyanide to Fish and Wildlife related to its use in Mining

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ABSTRACT This review of cyanide chemistry, toxicology and destruction practices includes:
1. An introduction to basic cyanide chemistry and the commonly occurring forms of cyanide
Cyanide is supplied to the minerals industry as an alkali metal salt such as sodium cyanide, NaCN. This salt is dissolved in water liberating "Free Cyanide," either HCN, Hydrocyanic acid (Hydrogen Cyanide gas), or CN^-, the cyanide ion. When introduced to a slurry of ground ore, free cyanide reacts with metals to produce metallocyanide complexes. Cyanide complexes that release free cyanide under weakly acid conditions, are termed WAD (Weak Acid Dissociable) Cyanide. "Total Cyanide" includes "free cyanide," "WAD Cyanide", more stable cyanide complexes (primarily iron cyanides) and organic cyanides (the nitriles).
2. A review of toxic effects of cyanide and cyanide complexes to fish and wildlife
HCN is the most toxic form of cyanide. The toxicity of cyanide compounds usually depends upon their ability to dissociate to yield free cyanide, but copper and silver cyanides are toxic in their own right. Cyanates (CNO^-), and thiocyanates (SCN^-), are also toxic by-products of cyanide use. Thiocyanate produces "sudden death syndrome" (SDS) in fishes at widely varying concentrations because fish accumulate thiocyanate. Toxic effects of cyanide to fish are increased by low water temperatures and low dissolved oxygen concentrations. Cyanide and related compounds also affect growth and behavior of fishes.
3. A comparison of the chemistry and environmental implications of various cyanide destruct processes, and their by-products
Common cyanide "destruct" practices include: natural degradation, bacterial degradation, alkaline chlorination,hydrogen peroxide oxidation and the INCO SO_2/Air Process. Most cyanide destruct processes oxidize cyanide to cyanate. Further oxidation yields ammonia (which can be as toxic as cyanide). Reagents, such as chlorine, can be highly toxic and may also produce undesirable by-products.

INTRODUCTION

Cyanides are simple, common, and highly toxic molecules that contain a carbon atom triple bonded to a nitrogen atom, commonly called cyanide and represented in chemical notation as CN. This triple bonded carbon and nitrogen forms CN^- ions in basic aqueous solutions, and is used by the mining industry to dissolve and extract gold from ores. The resultant tailings and effluents contain cyanides, various derivative compounds, and metallic cyanide complexes, all of which must be detoxified or disposed of on lands, and into waters, at levels which will not adversely affect fish or wildlife.

BIOCHEMICAL PROPERTIES

Cyanide (CN^-) is a simple and common ion formed as a metabolic intermediate by many plants and animals. Cyanide commonly exists as either simple hydrocyanic acid or hydrogen cyanide gas (HCN), or as alkali metal salts such as sodium cyanide (NaCN), or potassium cyanide (KCN).

The cyanide ion reacts in a manner similar to that of the halide ion and combines with most metals to form complexes. Cyanide in a mining effluent exists in many forms, most of which have no established water quality criteria.

Cyanide is toxic because it inhibits the cytochrome oxidase system, which is responsible for electron transfer in respiration. Cyanide is a non-cumulative, protoplasmic poison which may arrest the respiratory activity of all animal life (Doudoroff 1976). Death from acute cyanide poisoning is essentially by asphyxiation. Most cyanide complexes and derivatives are far less toxic than molecular HCN; so much so, that there is a controversy over whether the appropriate measure for water quality is free cyanide, or total cyanide (see Terminology, below).

Terrestrial vertebrates may be exposed to cyanide by breathing HCN gas, by drinking water containing cyanides, or by eating cyanides or cyanogenic plants. Fish and

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amphibians are at greater risk because they may also absorb HCN through their skins and they may not avoid exposure as readily.

Although fish appear to be the most sensitive to cyanide toxicity among vertebrates, the death of birds from drinking tailings pond or process waters at mines employing cyanide to extract gold (at the rate of hundreds per month) has probably raised the greatest public concern and awareness of cyanide poisoning. Unfortunately Hill (1990) found that an "extensive literature search failed to provide information on the toxicity of NaCN or related cyanide formulations and forms to any waterfowl, wading, or shore bird species, on cyanide toxicity when administered in water to any species, on effects of fatigue and dehydration on tolerance of cyanide poisoning, on practical concentrations of cyanide occurring in variously sized puddles, streams and impoundments from different mining methods, or on interaction between cyanide and water quality including factors of pH and presence of heavy metals."

Chronic effects of cyanide intoxication in mammals include demyelination of nerves, lesions of the optic nerve, decrease in sulfur containing amino acids, increase in thiocyanate, goiter, ataxia, hypertonia and depressed thyroid function (Ermans et al. 1972 cited in Solomonson 1981). These sublethal effects of chronic cyanide exposure are common in humans in tropical regions where cassava (a cyanogenic plant) is a staple part of the diet. A person consuming 750 grams of cassava daily, an amount capable of generating at least 35 mg. of HCN, may receive half of a lethal dose of cyanide every day (Cooke and Coursey, 1981).
Cyanide is found in emissions from automobiles with malfunctioning catalytic converters, in smoke from burning plastics (polyurethane in particular), and in tobacco smoke where it may cause tobacco amblyopia (or dimming of vision)(Way 1981).

TERMINOLOGY

Cyanide exists in various forms in aqueous solutions and readily forms complexes with metals, sulfides and organic compounds.

Cyanide Ion

The cyanide ion (CN^-) is formed by the ionization of Hydrocyanic Acid (HCN) in water. Only in highly basic solutions is an appreciable fraction of the HCN ionized. At water temperatures between 20 and 25° C, 99.5% of the free cyanide occurs as HCN at pH 7, 91% as HCN at pH 8.3 and even at a pH of 9.0, (not likely to occur in natural waters) 66% of the free cyanide is in the form of molecular HCN (Doudoroff 1976). Acute toxicity of solutions containing cyanide related compounds is usually due to the presence of molecular HCN.

Free Cyanide

Free cyanide refers to the total of the CN^- ion and molecular HCN in a solution. Only the weight of the cyanide group (CN^-), is usually reported as the free cyanide concentration of a solution. However, HCN is almost always the predominant component of the free cyanide in aqueous solutions. Free cyanide is generated by solution of simple cyanides such as NaCN, or the dissociation and decomposition of cyanide complexes with metals, the metallocyanide complexes, and organic compounds, the nitriles.

Weak Acid Dissociable, WAD Cyanide

Cyanide complexes readily with metals, which is the basis for its use in the refining of gold ores. However, the metallocyanides tend to dissociate to various degrees in acids (depending on the metal and the pH), liberating CN^- and HCN. Iron cyanides are not weak acid dissociable.

Total Cyanide

Total cyanide includes all species of cyanide in a solution that can be measured by a standard analytical technique involving acid distillation. Total cyanide is determined from the amount of cyanide thus liberated as CN^- and HCN. Doudoroff (1976) argues that the term "total cyanide" is misleading in that not all cyanide that is present is measured, and some cyanide may even be generated by the analysis. Total cyanide includes all of the metallocyanides as well as organic cyanide compounds, the nitriles.

Cyanate ion, CNO^-

Cyanate (CNO) is formed from the oxidation of cyanide. Chemical oxidation of cyanide is the standard means of cyanide destruction employed in the mining industry:

$$HCN \text{ (hydrogen cyanide)} + 1/2\ O_2 = HCNO \text{ (hydrogen cyanate)}$$

Cyanate may then be hydrolyzed in water to yield ammonia and carbon dioxide:

$$HCNO + H_2O = NH_3 + CO_2$$

Ammonia is about as toxic to fish as HCN, so that reduced toxicity of a solution as a result of cyanate decomposition may be offset by production of ammonia (National Park Service 1985). In cyanide destruct processes employing chemical oxidation, complete oxidation of cyanates to carbon dioxide and nitrogen is desired, but not always achieved.

Thiocyanate, CNS^-

Anaerobic decomposition of cyanide initially yields thiocyanate:

$$HCN + S = HCNS \text{ (hydrogen thiocyanate)}$$

$$HCNS + 2H_2O = H_2S \text{ (hydrogen sulfide)} + CO_2 + NH_3 \text{ (ammonia)}$$

Note that both ammonia and hydrogen sulfide are highly toxic. Thiocyanate may be biodegraded by anaerobic bacteria, but is more stable than cyanate (National Park Service, 1985).

Thiocyanate is much less toxic than cyanide, but may produce "Sudden Death Syndrome" in fishes at varying, otherwise sublethal, concentrations. Toxicity of thiocyanate may be explained in part by the presence of an enzyme or enzymes in red blood cells that converts thiocyanate back to cyanide (Goldstein and Rieders 1963).

In mining, thiocyanate is readily formed when cyanide is used to extract metals from ores containing sulfides. Thiocyanate also complexes with metals in solution to form metal-thiocyanate complexes. If both cyanide and thiocyanate are present in solution with metals, the metal-cyanide complexes are formed in preference to the metal-thiocyanates.

Many of the metal-thiocyanates are relatively insoluble and may form precipitates. Complexation of metals with thiocyanate may serve to remove both metals and cyanide from effluent waters (NPS, 1985). However, metals, thiocyanate, ammonia, hydrogen sulfide, and hydrogen cyanide may all be liberated as a result of conditions at membrane surfaces and within the bodies of organisms.

Free Cyanide, WAD Cyanide or Total Cyanide?

According to an extensive review by Doudoroff (1976), the toxicity of cyanide polluted waters is due almost entirely to molecular hydrocyanic acid, HCN. The cyanide ion (CN^-), is not readily formed at the pH of natural waters. As noted above, even at pH 9, two thirds of the free cyanide (HCN and CN^-) is in the form of molecular HCN. Free cyanide is so much more toxic than other cyanides that Doudoroff argues "total cyanide determinations made and reported routinely in the past are often insufficiently instructive, if not meaningless, as measures of water quality."

In solutions of several cyanide related compounds, the toxicities of cyanates, thiocyanates, nitriles and metallocyanate is so much overshadowed by the toxicity of HCN that the effects of less toxic compounds are difficult to measure and easily overlooked.

However, weak acid dissociable (WAD) cyanide may easily become free cyanide in acid environments, including those inside digestive tracts and blood vessels, and at membrane surfaces.

There are also some compounds, primarily the iron cyanides, that are not either readily water soluble nor acid dissociable, but are broken down by sunlight to yield free cyanide. This photolysis may liberate HCN into the atmosphere or generate toxic concentrations of HCN in a tailings pond.

Rather than being "meaningless" as suggested by Doudoroff (1976), it appears that all three cyanide measures are toxicologically instructive, and are particularly so when viewed together.

EPA WATER QUALITY CRITERIA

The current U.S. Environmental Protection Agency (EPA) water quality criterion for total cyanide is 5.2 ug/L for fresh water and 1.0 ug/L for marine aquatic life and wildlife (EPA 1986). In review of the 1976 EPA standard for the American Fisheries Society, Doudoroff et al. (1979) noted that the HCN ion is no less available at the pH of sea water than at lower pH. Further, the reviewers cite evidence that free cyanide can be more toxic to fishes in saltwater than fresh water at the same pH. However, the detection limit for total cyanide is about 5.0 ug/L, if a ten fold concentration step is incorporated into the analytical method (Ursula Spannagel, Alaska Department of Environmental Conservation, Juneau, Alaska, pers. comm. 1990).

There are no criteria for other toxic derivatives of cyanide, particularly cyanate, thiocyanate, and the metallocyanides such as the silver and copper cyanides.

TOXICITY

The information presented below is the result of laboratory studies of specific actions of individual toxicants on individual species. The effects of multiple toxicants upon many species functioning as an ecosystem are not so clearly defined.

The discussion focuses primarily upon cyanide toxicity to fish because fish are killed by relatively low cyanide concentrations (in the parts per billion range while avian and mammalian deaths are caused by cyanide concentrations on the order of parts per million) and because there is relatively little published information on cyanide toxicity to any other vertebrate group (Hill, 1990). It is interesting to note that because cassava, a cyanogenic plant, is a staple part of the diet of humans in tropical areas, there is probably more known about the chronic effects of cyanide to humans than any other group of animals (Nartley, 1981).

Cyanide Smith et al. (1979) reported that juvenile fishes are the least tolerant to cyanide, and that 96 hour LC_{50} values, for well oxygenated cyanide solutions at 9° C, ranged from 57 ug/L for rainbow trout to 191 ug/L for wild fathead minnows. Spawning of the bluegill sunfish was completely inhibited at 5 ug/L HCN (Hemming and Thurston 1985). Kimball et al. (1978) also found that spawning of bluegills was inhibited by concentrations below 5.2 ug/L at 25° C, and noted that decreasing temperature tends to increase the sensitivity of fishes to cyanide (see temperature effects below).

Kimball et al. (1978) reported a set of signs which resulted in death of adult bluegills after two weeks, and which began

with the onset of the spawning period. At concentrations of 9.8 ug/L and above, bluegill adults first showed a lack of feeding activity and impaired ability to judge distances to food and capture it. Affected fish then began listing to one side, and displayed spiraling and darting motions, finally coming to lie, often upside down, on the bottom of the test tank until dead.

Free cyanide concentrations on the order of 10 ug/L can "rapidly and lastingly" impair swimming ability of salmonids in oxygenated water. At temperatures near $0^{o}C$, lethal concentrations may be as low as 20-25 ug/L. At low oxygen concentrations, susceptibility to cyanide poisoning is markedly increased (Doudoroff 1976).

Fish embryos and young larvae have been shown to be far more resistant to free cyanide than adults, but this resistance is evidently not a universal trait of fishes. Cairns, et al. (1965, cited in Doudoroff 1976), reported a 48 hour median tolerance limit of 11.7 mg/L CN for zebra danio (Brachydanio rerio) embryos and a median tolerance limit of 0.49 mg/L CN for adults. However, controls developed eye pigmentation within 24 hours, while the experimental group, though tolerant of cyanide, did not develop eye pigmentation in this period. Karsten (1934, reported in Doudoroff, 1976) found that day old brown trout sac fry were resistant to and developed normally after exposure to 3.2 mg/L CN, but that 20-23 cm. long brown trout were killed by this free cyanide concentration within 7 minutes. On the other hand, Phillips (1940, cited in Doudoroff 1976) found that embryos of the cunner, Tautogolabrus adspersus, a marine fish, were intolerant of a CN concentration of 0.65 mg/L.

Many plants produce cyanogenic compounds in small but sufficient quantities to kill grazing animals that eat them. At chronic exposure levels, cyanide compounds in peas and plants of the genus Lathyrus can cause lathyrism, skeletal and nerve damage resulting from interference with the cross linking of collagen molecules in connective tissues (Reed 1985). However, cyanide is generally toxic to plants.

In air, concentrations of HCN above 200 ppm. are rapidly lethal to mammals and other terrestrial vertebrates. Concentrations of 80 to 160 ppm. can cause sublethal toxic effects. However, concentrations of 300 ppm. CN in the diet of rats produced "little chronic effect" after a period of up to three years (Howard and Hanzal 1955 cited in Feigly et.al. 1985). Philbrick (1979 cited in Feigly et al. 1985) observed no toxic effects to rats fed diets containing 1500 ppm.. potassium cyanide or 2240 ppm. potassium thiocyanate for a period of 11.5 months.

Wiemeyer et al (1986) found marked differences in toxicity of orally administered NaCN among species of birds. The LD_{50} of NaCN for black vultures was estimated to be 4.8 mg/kg. while the NaCN LD_{50} for starlings was determined to be approximately 17 mg/kg. Sensitivities to cyanide seemed to be correlated with diet rather than body size. Three flesh eating species showed lower LD_{50}'s than those feeding primarily on plant material (Wiemeyer et al 1986).

Deaths of hundreds of birds per month from drinking cyanide in tailings and process pond waters have be documented in arid regions of the western United States. Bird deaths at the Paradise Peak mine in Nevada declined dramatically when cyanide levels in the tailings pond were reduced below 50 parts per million (Allen 1990). However, Hallock (1990) cautions that aqueous cyanide concentrations less than 50 ppm. are not "safe concentrations" and that "the Fish and Wildlife Service has no data upon which to define a universal toxic threshold (to birds) for cyanide solutions."

Towill (1978 cited in Feigley et al. 1985) concluded that CN does not bioaccumulate or biomagnify in ecosystems. However, an incident reported by Fellows (1985) showed that cyanide concentrations can build up in humans who have been exposed to cyanide for a number of days, because the body may not be able to discharge or detoxify the cyanide quickly enough. In this case, even though the exposure was less than the 10 ppm. (in air) maximum permitted by EPA regulation, workers at a cyanide leach facility (percolation of HCN through piles of ore in the open air) developed symptoms of cyanide poisoning over the course of the work week, but the symptoms disappeared following the weekend. The bodies of the workers did not completely remove the daily cyanide dose, so that cyanide poisoning developed over the course of several days of exposure.

Feigly et al. (1985) were unable to detect adverse effects on rodent populations, of cyanide heap leaching gold recovery operations at a facility in South Dakota. This they attributed to the ability of animals to metabolize and detoxify cyanide to thiocyanate, the low toxicity to mammals of low cyanide concentrations, and the lack of bioaccumulation of cyanide by animals. In a group discussion at the Nevada Wildlife/Mining Workshop in March 1990 representatives of mining, wildlife management, cyanide manufacturing (Dupont), and conservation interests (Sierra Club) seemed to agree that cyanide evaporating from the surface of tailings and mine process ponds is at such low concentrations in air that it poses little hazard to wildlife (Nevada Wildlife/Mining Workshop 1990).

Cyanates

The cyanate ion (CNO^-), is a product of commonly used cyanide destruct processes. Cyanate may persist in water for a long time but it may also be hydrolyzed to yield ammonium and carbonate ions. The tolerance limit for the creek chub,

Semotilus atromaculatus, to sodium cyanate (NaCNO), is reported to be about 75 mg/L; and 75 mg/L is reported as the lower limit of harmful concentrations of KCNO (Doudoroff 1976).

Thiocyanate

Enzymatic conversion of cyanide to thiocyanate in the blood is the primary method of cyanide detoxification in vertebrates. This process requires sulfur and tends to deplete the available sulfur including the sulfur bearing amino acids, leading to vitamin B12 deficiency, cretinism, and mental retardation in humans (Nartey 1981). Additionally, thiocyanate depresses thyroid function by inhibiting the uptake of iodine by the thyroid gland and the organic binding of iodine in thyroid tissues (Solomonson 1981).

Thiocyanate may also be converted back to cyanide in the blood by enzymatic reactions. Goldstein and Rieders (1953) found that most of this conversion occurred in red blood cells. Westley, (1981) attributes the conversion of thiocyanate to cyanide, to the oxidation of thiocyanate catalyzed ty peroxidases, methemoglobin and oxyhemoglobin:

$$SCN^- + H_20_2 = CN^- + S0_4^{-2} + 2\ H^+{}_30$$

(from Westley 1981)

Westley (1981) notes that not only is this a "nuisance for all organisms that must detoxify cyanide. Further it is a nuisance exacerbated by the rather low rate of excretion of thiocyanate ion. The kidneys filter out SCN^- well enough in the glomeruli but, unfortunately, also resorb it well in the tubules." Conversion of thiocyanate to cyanide in the blood, may have some bearing on the observations of Sudden Death Syndrome in trout, described below.

In fish, LC_{50} values for thiocyanate are difficult to determine because the results vary so widely. Doudoroff (1976) reports effect thresholds at concentrations from 29 to 5,000 mg/L SCN^-, and the U.S. Environmental Protection Agency has no criterion for thiocyanate. Results reported by Heming et al. (1985) showed that the 96 hour LC_{50} for thiocyanate toxicity to brook trout was likely to be within the range of 24 - 70 mg/L.

Acute lethal effects of thiocyanate to fish are characterized by what Heming et al. (1985) termed Sudden Death Syndrome (SDS). SDS is characterized by convulsions, gasping, loss of equilibrium, and buoyancy, flaring of the operculae, darkening of the skin, cessation of ventilation, and extreme rigor, in a matter of minutes of the onset of distress. SDS was triggered by strenuous exercise, abrupt changes in photoperiod, and increased levels of spontaneous activity.

Heming et al. (1985) proposed that SDS in fish may involve a direct effect of SCN^- on neuromuscular functions. Uptake of thiocyanate was inhibited by chloride concentrations, and was accompanied by a decline in the plasma Cl^-, leading Heming et al. (1985) to suppose that SCN^- was being substituted for Cl^- at the HCO_3^-/Cl^- exchange sites of the gills.

Brook and rainbow trout are capable of accumulating thiocyanate at a rapid rate, against its concentration gradient. SDS was closely correlated with blood plasma SCN^- concentrations and occurred in half of the fish when plasma concentrations reached approximately 250 mg/L SCN^-. Heming et al. (1985) found that six to seven gram rainbow trout accumulated thiocyanate at a rate of approximately 870 mg/(L plasma x day x kg.). They speculated that at 1.0 mg/L SCN it would take one to two months for 50% of the exposed population to be at risk of SDS.

As stated above, conversion of cyanide to thiocyanate is the primary means of cyanide detoxification in animals. However, thiocyanate inhibits transport of halides in the thyroid, stomach, cornea and gills, and inhibits enzymes such as succinic anhydrase and ATPase. Toxic effects to humans include central nervous system effects such as irritability, nervousness, hallucinations, psychosis, mania, delirium and convulsions. These toxic effects may be due in part to the conversion of thiocyanates to cyanide, but antidotes for cyanide have no effect on the acute toxicity of thiocyanate to trout (Heming and Thurston 1985).

Metallocyanides

Cyanide combines with metals to form complexes that are generally less toxic, than free cyanide. However, soluble metallocyanides dissociate to yield hydrogen cyanide, which is the usual cause of their toxicity, though some, such as silver, copper and nickel cyanides may be quite toxic in their own right. The iron cyanides are interesting because they are not particularly toxic, yet liberate free cyanide on exposure to sunlight (Doudoroff 1976).

A. Zinc and Cadmium Cyanides

Very dilute solutions of either zinc or cadmium cyanide are almost completely dissociated at pH levels common in natural waters. These dilute solutions are still acutely toxic and owe their toxicity to that of the heavy metal ion as well as the HCN formed by their dissociation. There may be a synergistic relationship between the toxic actions of the free cyanide and the zinc and cadmium ions (Doudoroff 1976).

B. Nickel-Cyanide

Complexation of cyanide with nickel can prevent toxicity to fish in alkaline waters (at or near pH 7.5), but in more acid conditions (pH 6.5) may have no effect at all due to the dissociation of nickelocyanide in acidic environments and the production of molecular HCN.

The $Ni(CN)_4^{-2}$ ion may be absorbed by fish tissues in concentrated, alkaline nickelocyanide solutions, and this may account for the apparent increase in toxicity of these solutions over what would be expected from their free cyanide content alone (Doudoroff 1976).

Doudoroff (1956, cited in Doudoroff 1976) observed that before they died, the bodies of fathead minnows exposed to concentrated but not rapidly lethal solutions of nickelocyanide became swollen and blotched with red hemorrhages, perhaps because of osmoregulatory failure.

C. <u>Silver Cyanide</u>
The $AgCN^-$ ion itself has a fairly high toxicity to fish. Pronounced superficial coagulation of mucus, suggestive of heavy metal poisoning, was also observed in fish exposed to lethal silver cyanide solutions. In contrast to other toxic cyanide metal complexes, most of the cyanide remains bound to the silver in solutions regardless of pH. The 96 hour mean tolerance limit of $Ag(CN)_2^-$, for bluegills, is somewhat less than 7 mg/L as CN^- (Doudoroff 1976).

Silver complexed with cyanide is accumulated in the internal organs and blood, rather than in the gills, as is the case with silver nitrate. The silver cyanide ion passes through the gills and into internal organs faster than the nickelocyanide ion but more slowly than the cuprocyanide ion.

The silver ion is one of the most toxic metal ions. At very low silver cyanide concentrations and low pH, the toxicity of the free silver ion is predominant over the silver cyanide ion or the HCN present in solution. The chronic toxicity of the metallocyanide complexes needs to be investigated (Doudoroff 1976).

D. <u>Copper-Cyanide Complexes</u>
When combined, the cupric ion and free cyanide react to detoxify each other. However, undissociated cuprocyanide and copper ions both contribute to the toxicity of cuprocyanide solutions. The high toxicity of solutions of cuprocyanides with very low HCN levels is attributed by Doudoroff (1976) to the toxic action of cuprocyanide complex ions. The 48 hour median tolerance limit of bluegills to the $Cu(CN)_2^-$ ion in slightly alkaline solutions is about 9 mg/L at 20° C.

The $Cu(CN)_2^-$ ion enters the bodies of fish quite rapidly, at nearly four times the rate at which the silver cyanide ion is absorbed. This may be the reason for the greater toxicity of the copper cyanide complexes. Like the silver cyanide complex, the cuprocyanide complex produces signs of heavy metal poisoning, including coagulated mucus on gills and body surfaces of intoxicated fish.

E. <u>Iron Cyanides</u>
The iron cyanides are very stable compounds and do not readily dissociate in water. However, they may be photolyzed, broken down by light, to produce free cyanide. The rapidity or completeness of this decomposition is dependent on the quality and intensity of the light, and is highly variable and unpredictable. Doudoroff (1976) concludes that were it not for photolysis, surface waters would never be rendered acutely toxic to fish by "moderate amounts" of ferro or ferricyanides.

Iron cyanides will slowly dissociate in the dark, and ferrocyanides are less stable than ferricyanides.

F. <u>Nitriles</u>
The nitriles are organic cyanides and vary considerably in their toxicity to fishes. Though nitriles may be unlikely constituents of most cyanide gold extraction processes, malano nitrile ($NCCH_2CN$) is, like cyanide, used to extract gold from ores.

Doudoroff's (1976) review of the literature found malononitrile, to be the most toxic of the nitriles discussed, and it is a cumulative toxin. Median survival periods of rainbow trout exposed to concentrations of 32, 5, and 0.5 mg/L were about 5 hours, 32 hours, and 3 days respectively, and these results suggest that the lethal threshold concentration of malononitrile may be as low or lower than that of free cyanide.

G. <u>Cyanogen Chloride</u>
Cyanogen chloride (CNCl) is produced by combination of chlorine with cyanide or thiocyanate, and may be more toxic to fish than free cyanide. The theoretical threshold toxicity of cyanogen chloride to rainbow trout may be as low as 80 ug/L as CNCl (Doudoroff 1976). Cyanogen chloride may be produced in the alkaline chlorination cyanide destruct process.

FACTORS INFLUENCING TOXICITY

A. <u>pH</u>
Increasing pH decreases the concentration of HCN and thereby decreases the acute toxicity of free cyanide in solution. However, the HCN concentration does not change substantially below a pH of 8.0, so natural waters owe their free cyanide toxicity to molecular HCN (Doudoroff 1976).

B. <u>Temperature and Dissolved Oxygen</u>
There appears to be a marked difference in temperature effects on the toxicity of weak or more concentrated solutions of free cyanide.

Doudoroff (1976) cites a study at test temperatures of 12-13° C, which estimated the lethal threshold concentration of free cyanide to rainbow trout to be about 0.8 mg/L as CN^-. However, at a temperature of 3° C the lethal threshold was reduced to about 0.2 mg/L.

At higher cyanide concentrations, above 1 mg/L, there is an inverse relationship between temperature and concentrations producing acute toxicity in fish. Two or threefold increases in cyanide toxicity with each 10° C increase in temperature have been recorded (Doudoroff 1976).

The resistance of fish to cyanide poisoning at a given temperature is dependent upon the temperature to which they are acclimated (see also Cyanide Acclimation, below). Fish acclimated at low temperatures are less resistant to cyanide in higher temperature water, while fish acclimated to higher temperatures are more resistant to cyanide in lower temperature solutions (Doudoroff 1976).

Free cyanide toxicity to fish increases with decrease in oxygen concentrations, and this effect is more pronounced at low cyanide concentrations. Doudoroff (1976) cites results that showed a 100 fold increase in the tolerance of yearling rainbow trout to a free cyanide concentration of 0.105 mg/L, as dissolved oxygen increased from 3 to 9 mg/L.

C. <u>Salinity and Hardness</u>
Broderius (1973, cited in Douderoff 1976) demonstrated that threespine sticklebacks were about twice as sensitive to cyanide (0.27 mg/L as CN) in seawater with a chlorinity of 16-17 parts per thousand than they were in freshwater. However, other studies cited by Doudoroff (1976) showed no effect of salinity on the cyanide tolerance of juvenile rainbow trout.

Doudoroff (1976) found no convincing evidence in the literature that water hardness affects the toxicity of cyanide to fishes.

D. <u>Cyanide Acclimation</u>
There is some evidence to suggest that acclimation to sublethal levels of free cyanide may increase the resistance of fish to lethal but dilute cyanide solutions, while increasing their susceptibility to higher lethal levels. Doudoroff (1976) suggests that this could be due to a mechanism that increases the tolerance to cyanide initially, but at higher concentrations in the cyanide acclimated fish, this mechanism is injured to the point that it does not operate at all, and the acclimated fish are less tolerant to cyanide.

E. <u>Body Size</u>
Results vary widely and, therefore, the differences in the free cyanide resistance of fish of different body sizes is not demonstrated by Doudoroff's (1976) review of the literature.

F. <u>Avoidance Reactions</u>
Reactions of fishes to cyanide are mixed. Doudoroff (1976) reports Costa's (1956) study which demonstrated avoidance of brown trout, the minnow, Phoxinus phoxinus, and the threespined stickleback, of a solution of 0.026 mg/L free cyanide. Responses of these fishes were not immediate or definite at this concentration, and young eels and goldfish showed no reaction. At a concentration of 1.3 mg/L CN all species tested showed definite avoidance reactions.

Doudoroff (1976) concludes that the uncertain reactions of fishes to cyanide should not lead one to conclude that fish will avoid fatal concentrations of cyanide by swimming away from them.

G. <u>Other Sublethal Effects</u>
The swimming ability of brook trout was impaired by a month-long exposure to cyanide concentrations of 10, 20, and 50 ug/L, with duration of swimming reduced by 75, 90, and 98 percent respectively (Niel 1957, reported in Doudoroff, 1976). This impaired swimming ability continued for at least 20 days, at which point mean swimming time of cyanide exposed fish was 80 percent that of controls.

Broderius' (1970, cited in Doudoroff, 1976) work with coho salmon showed results that were not as dramatic. Swimming times were reduced 56 percent at 10 ug/L CN and 85 percent at 50 ug/L CN, but only two hours exposure was required to produce these results.

Smith et al. (1979) working with fathead minnows, brook trout, and bluegills, demonstrated a decline in the number of eggs produced per female with increasing cyanide concentrations. In brook trout, Smith et al. (1979) found that at concentrations above 5.7 ug/L, the number of eggs per female decreased linearly with increasing CN concentration; the decrease in egg production was approximately 1.2% for each increase of 1 ug/L CN. Eggs were not viable at HCN concentrations above 64.9 ug/L. There were no significant differences in egg viability demonstrated at lower cyanide concentrations, and sperm motility also showed no significant differences in any of the cyanide concentrations tested (5.7 - 75.3 ug/L).

Growth rate may be affected by cyanide initially, but it appears that fish may compensate for reduced efficiency of food conversion by increasing their food consumption in cyanide contaminated waters. Doudoroff (1976) concludes that growth rate is not a very sensitive measure of cyanide poisoning to juvenile salmonids. On the other hand it may be significant that cyanide stressed fishes have to eat more to maintain their body weight.

Smith et al. (1979) found that growth of juvenile fishes was initially retarded by HCN, but that depending upon concentration, cyanide exposed juvenile fish might grow faster or slower than controls. For example, brook trout showed no difference in growth from controls after 30 days exposure to cyanide at ll ug/L, but growth was greater at 5 ug/L, and less at concentrations above 11 ug/L.

Body proportions may also be altered. Cichlids showed excessive increases in body depth and width suggesting impaired growth in length, and those exposed to concentrations of 90 ug/L CN had abnormally brittle fins. Increases in proteolytic digestive enzyme activity in the intestinal tissues of cichlids exposed to cyanide were thought by Doudoroff (1976) to be related to increased food consumption in cyanide exposed fishes.

Cyanide exposed fishes that were starved for up to 24 days lost four times as much weight as controls at a cyanide concentration of 90 ug/L (Leduc 1966, reviewed in Doudoroff 1976).

Osmoregulation in rainbow trout was inhibited by a 28 day exposure to cyanide concentrations as low as 10 ug/L. In saline solutions, cyanide exposed trout had higher plasma osmotic pressures and chloride concentrations than controls. When returned to fresh water plasma osmotic pressures and chloride concentrations in cyanide exposed trout were lower than controls (Chan 1971, reported in Doudoroff 1976).

Cyanide Destruct Processes

There are at least five methods of promoting cyanide destruction used in the mining industry:

1. Natural Degradation: Aging of solutions in shallow ponds to photolyze iron cyanides and allow for the escape of HCN gas into the atmosphere.
2. Biodegradation using bacteria: So far this process is used very successfully, but only by the Homestake Mine in Colorado (Whitlock 1990).
3. Alkaline chlorination: At high pH chlorination yields cyanate, nitrogen, and carbon dioxide.
4. Oxidation with hydrogen peroxide: In the presence of a copper catalyst, peroxide oxidation yields cyanate.
5. The Inco SO_2/Air Process: At high pH, in the presence of a copper catalyst, SO_2 oxidizes cyanide to cyanate.

Alkaline Chlorination

In alkaline chlorination, either chlorine gas or calcium or sodium hypochlorite is used at elevated pH to oxidize free cyanide and weakly bonded cyanide complexes to cyanate (Scott 1989). Further addition of chlorine and longer retention times may be used to oxidize cyanate to nitrogen and bicarbonate.

Cyanogen chloride is a highly toxic compound formed in the alkaline chlorination process at low pH. Because the process produces hydrochloric acid when large amounts of hypochlorite are used, control of pH is critical to avoid producing cyanogen chloride. At concentrations over 1% of chlorine and cyanide, cyanogen chloride gas may also be generated at elevated pH (National Park Service, 1985).

The complete process may take over two hours, and can consume in excess of eight parts chlorine per one part of free cyanide. Other than producing cyanogen chloride, the process may have the disadvantage of incompletely oxidizing the cyanide. The chlorine content of the treated solution is also increased, and can be harmful to aquatic species in receiving waters. Iron cyanides are not removed.

Hypochlorite also reacts preferentially with thiocyanate over free cyanide, so in solutions with high thiocyanate concentrations, free cyanide may remain unchanged. Thiocyanate is commonly formed in the leaching of sulfide ores, requiring two to four times the amount of chlorine predicted to destroy the free cyanide (National Park Service, 1985).

Alkaline chlorination is the most widely recognized destruction process used in the mining industry in terms of engineering expertise and operating experience. However, Mc Gill and Comba (1990) note that "the residual chlorine compounds present can be toxic to aquatic life. In the case where decant waters are discharged, the solution will require dechlorination. Addition of SO_2 or sodium sulfite has been effective in dechlorination of the solutions." They conclude that if "removal of iron cyanides is not required and the initial thiocyanates are low, not causing prohibitive chlorine consumption, alkaline chlorination provides a viable treatment method for the removal or weak-acid-dissociable cyanide and metals. Although this method of cyanide destruction has been used in the mining industry for years, it is often being replaced by new generation techniques such as the oxidative hydrogen peroxide and SO_2/air processes."

Scott (1989) reported that of 50 canadian mills which used cyanidation in 1988, 23 (46%) employed cyanide destruction, 10 used the SO_2/air process, 12 used H_2O_2 (hydrogen peroxide). The one mine which used alkaline chlorination to destroy cyanide in 1988 switched to H_2O_2 in 1989. Alkaline chlorination was the first cyanide destruct process used in Canada, but it has "almost fallen into disuse in favor of more effective and less costly methods (Scott 1989)." Scott concludes that "the chief disadvantages of alkaline chlorination are: the inability to remove iron cyanide, the cost, and the occurrence of residual chlorine at concentrations toxic to fish, to name just three."

Hydrogen Peroxide Oxidation

Like alkaline chlorination, hydrogen peroxide oxidation also destroys free cyanide and weak acid dissociable cyanide complexes, but has the advantage of producing no toxic chlorine by-products. However, the process is slow and must be accelerated by the addition of copper or copper and formaldehyde (National Park Service 1985).

In the presence of copper, acting as a catalyst, hydrogen peroxide destroys free and metal complexed cyanides (except iron cyanides) by oxidizing them to cyanate. Cyanate is less toxic than cyanide but is not non-toxic.

Copper, zinc and nickel liberated from cyanide-metal complexes, form insoluble hydroxide precipitates. Excess hydrogen peroxide rapidly decomposes to water and oxygen. Removal of iron cyanide (too stable to be oxidized by hydrogen peroxide) is accomplished by complexing with copper to form a copper ferrocyanide, $CuFe(CN)_6$, precipitate (Scott 1989).

Inco SO_2/Air Process

The Inco SO_2/Air process uses a concentration of approximately five percent SO_2 in air to oxidize both free and metal-complexed cyanides, but not iron cyanides, to cyanate at pH 8-10 in the presence of a copper catalyst. Sulfur dioxide may be added as liquid SO_2, sodium bisulfite (Na_2SO_3), sodium metabisulfite ($Na_2S_2O_5$), or "roaster gasses" containing sulphur dioxide (Scott 1989). The oxidation of cyanide is represented by the equation:

$$CN^- + SO_2 + O_2 + H_2O = CNO^- + H_2SO_4$$

Once the cyanide has been oxidized, copper, zinc and nickel precipitate from the solution as hydroxides. Iron cyanide is removed by precipitation with copper or zinc to form (in the case of copper) copper ferrocyanide ($Cu_2Fe(CN)_6$).

When copper plays the dual role of catalyst and precipitant of iron cyanides, there must be sufficient amounts of copper to satisfy both reactions (Scott 1989)

Though cyanides and metal cyanide complexes are oxidized and removed, the SO_2/air process has little effect on thiocyanate (Hemming 1985).

SUMMARY

The following is a summary of the toxicities of cyanide related compounds to fishes:

CN^-

57 ug/L 96 hour LC_{50}	Rainbow Trout
10 ug/L Osmoregulation Inhibited	Rainbow Trout
9.8 ug/L Death with Onset of Spawning Period (2 week exposure)	Bluegill Sunfish
5 ug/L Spawning Inhibited	Bluegill Sunfish
10 ug/L Swimming Reduced 50% (2 hour exposure)	Coho Salmon
50 ug/Lug/L Swimming Reduced 85%(2 hour exposure)	Coho Salmon

(Lethality of Cyanide increases at low water temperatures, low dissolved oxygen concentrations. Lethality to sticklebacks increased with increase in salinity.)

CNO (Cyanate)

75 mg/L Lethal Threshold Concentration (Concentrations lethal to salmonids expected to be lower, based on sensitivity to cyanide)	Creek Chub

SCN (Thiocyanate)

250 mg/L In blood produces Sudden Death Syndrome in 50% of fish	Rainbow Trout

(Thiocyanate is accumulated above background concentrations)

$Ag(CN)_2^-$ (Silver Cyanide)

7 mg/L 96 Hour Mean Tolerance Limit (as CN)	Bluegill Sunfish

$Cu(CN)_2^-$ (Copper Cyanide)

9 mg/L 48 Hour Mean Tolerance Limit (as CN)	Bluegill Sunfish

CONCLUSIONS

1. The toxicity of simple cyanides and metallocyanides in natural waters is due primarily to HCN which is made available through dissociation, hydrolysis or photolysis.

2. HCN will generally be the most toxic constituent of a cyanide containing mining effluent. However, copper, silver, sulfur dioxide, and ammonia are also highly toxic.

3. It is difficult to measure cyanide concentrations at the very dilute levels that are required to avoid poisoning plants and animals, or meet state and federal water quality standards.

4. Weak cyanide concentrations are more toxic to fish at low oxygen concentrations and at temperatures near freezing. HCN will not evaporate from the surface of a waterbody when it is covered with ice. Therefore, winter conditions appear to increase the risk of fish kills by cyanides.

5. Poisons that operate on the same organ systems tend to be additive, if not synergistic, in their effects. Therefore the combined toxicity of cyanides, thiocyanate and cyanate need to be investigated.

6. Iron cyanides are relatively insoluble yet they are broken down by sunlight. Therefore iron cyanides may continue to be a source of cyanide pollution for many years.

7. The information presented above is the result of laboratory studies of specific actions of individual toxicants on individual species. The effects of multiple toxicants upon many species functioning as an ecosystem are not so clearly defined.

8. Concentrations of cyanide in a tailings pond will probably not be uniform. Prediction of risk to fish and wildlife depends upon the quantity of CN involved, whether a batch or continuous process is involved, water flow and channeling.

9. Thiocyanate toxicity in birds and mammals should be examined to determine if a phenomenon similar to Sudden Death Syndrome occurs in vertebrates other than fish.

10. Amphibians are likely to be as sensitive to cyanide as fish because the nature of their exposure is similar. However amphibians may be much more vulnerable to cyanide poisoning because their whole body surface may also used for respiration.

11. Cyanide "destruct" processes generally oxidize cyanide to cyanate and do not treat thiocyanate.

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Soil Disturbance Monitoring Transects
Thorne Bay Ranger District, Tongass National Forest

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SUMMARY: One hundred ninety soil disturbance trancsects were completed in timber harvest units on the Thorne Bay Ranger District, Tongass National Forest in southeast Alaska. Mineral soil disturbance on individual transects varied from 0 to 39 percent of the transect. Average disturbance of all transects was 4.6 percent. Shovel yarding averaged slightly higher levels of disturbance 5.1 percent, as compared to cable yarding systems which averaged 4.0 percent .

Comparisons were drawn between the Coffman Cove Administrative Area and the Thorne Bay Administrative Area. Shovel yarding on the Coffman Cove averaged 7.1 percent mineral soil disturbancem whereas shovel yarding on the Thorne Bay Area averaged 3.3 percent.

Differences in mineral soil disturbance between the two administrative areas can be explained by differences in operator experience or awareness and differences in timber sale administration. Once operators on the Coffman Cove Area tried to reduce soil disturbance, conditions improved and total distrubance was reduced.

Shovel yarding appears to have the higher potential for exposing mineral soil. When done improperly, shovel yarding can result in high levels of disturbance. Standards and guidelines for overall mineral soil distrubance were met in all the units involved in the study. Three units are borderline on acceptable distrubance (i.e. Confidence intervals overlap the acceptable level). Most of the exposed in these areas resulted from rutting in shovel yarded areas and skid trails in the case of one downhill hi-lead unit.

Effects of Heavy Recreation Use on Streambank Stability at Russian River and Proposed Solutions

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ABSTRACT: Russian River is a highly productive salmon stream on the Kenai Peninsula located near Cooper Landing, Alaska. The river provides spawning habitat for four species of salmon as well as rainbow trout and dolly varden. Sockeye salmon in particular are present in very large numbers, and provide a strong draw for anglers in South Central Alaska from late June through July. Three quarters of the state's population are located within a three hour drive of the Russian River, and in recent years about 70,000 anglers arrive annually to fish along its banks. This intensive use of the river has developed primarily over the past two decades. River users are now having an increasingly negative impact on the banks of the Russian. Soil compaction and extensive damage to the riparian vegetation have allowed for a major increase in stream bank erosion on the Russian. This has caused variable stream widening along the lower one and a half miles of the river. In a few cases, the river has widened by as much as 50 percent.

Progressive changes in river width are examined, primarily through use of historic aerial photography. Stabilization strategies are discussed for use on the Russian River. Primary emphasis for stabilization includes: 1) limiting angler foot traffic directly along the bank, 2) increasing bank durability in heavily used areas, and 3) planting of riparian vegetation along the stream bank.

Conifer, Shrub, and Forb Responses to Clearcut Logging by Plant Association on North Prince of Wales Island, Alaska

Thomas DeMeo

ABSTRACT:One hundred fifty transects were established in young even-aged stands on Prince of Wales and adjacent islands in southeast Alaska to estimate conifer, shrub, and forb cover following clearcut logging for five common plant associations or association groups (series). Data on tree overstory and understory cover, shrub cover, and forb cover were collected. Amount of blueberry (Vaccinium spp.) browsing by Sitka black-tailed deer (Odocoileus hemionus sitkensis) and slash depth were also recorded. Results showed conifer, shrub, and forb response differences among plant associations. Deer browsing was low for all associations. Thinning increased slash levels to original post-harvest levels.

Introduction:
Secondary forest succession, including understory composition and biomass, has been characterized for the western hemlock (Tsuga heterophylla (Raf.) Sarg.)-Sitka spruce (Picea sitchensis (Bong.) Carr) forest type in southeast Alaska (Alaback 1982, 1984). Following canopy closure, a depauperate stage-- a long period characterized by little understory growth other than mosses-- is well underway by age 40, and can last well beyond age 100. Recent work by Deal (in press), however, suggests than some productive stands may open sufficiently by age 60 to allow for some invasion of plants into the understory.

Soil disturbance plays an important role in determining the quantity and quality of understory vegetation following logging. Alaback (1984) used blueberry (Vaccinium spp.) and bunchberry (Cornus canadensis) as indicators of sites with relatively undisturbed soils. Indicators on alluvial sites were salmonberry (Rubus spectabilis) and trailing black currant (Ribes lacustre).

Young even-aged stands in southeast Alaska have not been stratified by plant association. Alaback (1984) worked with two broad forest zones-- Sitka spruce and western hemlock-Sitka spruce-- defined by Viereck and Dyrness (1980). Preliminary plant association classifications (Martin et al. 1981, Pawuk and Kissinger 1989, DeMeo 1989) now facilitate linking attributes of young even-aged stands to a wide range of site conditions.

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Mankowski and Peek (1989) stressed the importance of relating deer habitat use information to various successional stages. Clearly, the need for standardized descriptions of seral stages that follow clearcut logging, based on plant associations and site index, is evident.

The objectives of this study were two-fold: 1) To describe conifer regeneration, shrubs, and forbs in the years following clearcut logging to about age 25; and 2) To present this information in a form useful for direct application to integrated resource prescriptions, particularly those focused on timber production and maintenance of forage for Sitka black-tailed deer (Odocoileus hemionus sitkensis).

Methods:
This study took place on Prince of Wales Island (Polk Inlet northwards) and on adjacent islands along the west coast of Prince of Wales Island in the vicinity of Naukati. This area is at the southern end of the Alexander Archipelago, the chain of islands that makes up most of southeast Alaska.

Sampling began in the summer of 1988 when eighty transects were established on northern Prince of Wales Island in the vicinity of Hatchery Creek, Coffman Cove, Logjam Creek, North Thorne River, Thorne Bay, and North Pole Hill areas. Sampling focused on stands less than 20 years old.

An additional 70 transects were established in 1989. Emphasis was placed on sampling stands older than 20 yrs. Sampling focused on the limestone region of El Capitan, Naukati, and Tuxekan Island. Transects were also installed in precommercially thinned stands.

Sampling took place along permanently-marked transects. Typically one or two transects were established in a logging unit. Transects were permanently marked with a 6-ft. section

of reinforcing bar (rebar) or PVC pipe, and identified with an aluminum tag and flagging. Transects began at least 50 ft., and typically 100 ft., from the road edge and were generally located no more than 300 ft. from the road. Each transect was 100 ft. long. Initially, 20 one-m^2 plots were arrayed along one side of the 100-ft. line. Following trial sampling and data analysis, it was found 15 plots would yield data with the same confidence. For the remainder of the 1988 season, 15 plots were therefore used, spaced at random intervals along the line.

Percent cover of each vascular plant species was ocularly estimated on each plot. Trees were classified as understory or overstory, by species. The overstory/understory classification was relative to conifer size; i.e., a one-foot tall spruce, if the only tree on the plot, was classified as over- story, even if overtopped by a 3-foot tall layer of shrubs. On each plot, mean height was estimated for overstory and understory trees and for each shrub species using a graded height pole. The sampling procedure was reevaluated and modified for 1989 to accommodate monitoring of canopy gaps. Gaps were generally less than 100 ft. wide, so a shorter transect was in order. Plots along the transect were reduced from 15 one m^2 plots to 10 plots of 1 m^2 by 2 m^2 each. Total cover and height of the tree overstory, tree understory, and shrub layers was added. A decision was made to use metric units throughout. Light- weight PVC pipe was largely substituted for rebar in marking transects.

A total count of individual stems of shrubs was employed (Crocker-Bedford, pers. com., Shafer 1963, Stickney 1966). On each 1 m^2 by 2 m^2 plot, three blueberry (Vaccinium spp.) stems were randomly selected. Beginning at the tip of each stem, the observer worked downward, counting each branchlet and observing whether or not it had been browsed. On each stem, 11 branchlets were counted, for a total of 33 (3 stems X 11 branchlets). The number of browsed branchlets was then multiplied by 3 to yield a percent browsed estimate. Height and available forage of blueberry stems were tallied. Available forage was defined as percent cover of green material less than 1 m in height. The height of woody debris above the ground is a key factor in determining whether it will be an impediment to deer movement (Mankowski and Peek 1989). Three height classes were used: 0-30 cm., 30-50 cm., and 50 cm. or greater. Percent cover was estimated for each of the three levels. Slash recorded at one level was not duplicated at another.

Results and discussion

Figures were used to show understory and overstory response over time. Considerable variation is often typical of vegetation data, especially reconnaissance level data. Significant differences in the response data are often difficult to show, although trends may be present.

Conifer Response

The chief value of this figures that follow is in portraying the relative abundance of conifer species as the stand develops. As seen in Fig. 1, the ratio of overstory western hemlock cover to Sitka spruce cover is about 5:1 for the western hemlock/ blueberry association. Hemlock and spruce understory appear to peak at about age 5 and decline thereafter. Redcedar, while a minor component, does appear to modestly increase over time. For the shield fern association (Fig. 2), response is similar.

Dominance of western hemlock develops more rapidly, however, perhaps reflecting the more productive nature of these sites. (At ages 0-5, hemlock cover averages 29 percent, versus 10 percent for the hemlock/blueberry association.) At age 20 the same 5:1 ratio of hemlock to spruce is found for both shield fern and blueberry associations. Thinning acts to increase the proportion of spruce cover in the stand and decrease the hemlock proportion, as shown in Fig. 2. Hemlock declines from about 50 percent at age 20 to 36 percent four-five years following precommercial thinning. Spruce increases from 12 percent to 22 percent. The ratio of hemlock/spruce cover therefore changes from about 5:1 to about 3:2. Silviculturists on the Ketchikan Area typically aim to increase spruce to 20 percent cover following thinning (Tierney, pers. comm.). Data in Fig. 2 suggest they are meeting this target successfully, at least on the stands surveyed.

Data for Figure 2 was collected 4-6 yrs. following thinning; data on response at greater ages following thinning is scarce. Readers are referred to Alaback's (1984a) work on this topic; but that report, while far more comprehensive, is still based on stands 4-6 years following thinning. Hemlock response in hemlock associations characterized by devil's club (Fig. 3) lags behind that of blueberry associations. At ages 5-10 cover is about 10 percent in devil's club associations, compared with about 30 percent in western hemlock/blueberry (Fig. 1) and 40 percent in western hemlock/blueberry/shield fern (Fig. 2) associations. This Suggests thinning can be delayed until at least age 20 on devil's club sites.

Data for combined hemlock-redcedar associations (Fig. 4) also show a pattern of slow initial hemlock response. Hemlock overstory cover is about the same (15 percent) at age 10 in both western hemlock/devil's club and combined hemlock-redcedar associations. (Compare Figs. 3 and 4.) Mean hemlock cover at ages 20-30 does not increase over that for ages 15-20, but interestingly, spruce cover increases to nearly 30 percent. Redcedar cover in these associations is more consistently greater (5 percent) than in the hemlock series (1-5 percent), but the difference is probably not significant in a management context.

Figure 5 summarizes the comparison of hemlock response among the associations. The curves reflect the site differences related to each association. Hemlock/blueberry/shield shows earliest development of hemlock cover, because it represents

more productive sites and soils with generally undisturbed surface organic layers which are ideal for hemlock germination. Hemlock/blueberry shows parallel development, but at a slower rate. Combined redcedar associations show slow development, and at age 20 still lag behind the western hemlock/blueberry associations. Western hemlock/blueberry-devil's club is roughly similar to that of the redcedar associations. Thinning of the hemlock/blueberry shield fern association results in a hemlock cover decrease of 10-15% 4-5 years following precommercial thinning, because reduction of the hemlock:spruce ratio is often an objective of precommercial thinning (Tierney, pers. comm.).

Salmonberry Response

Shrub development following logging can be a major silvicultural concern. Shrubs can inhibit desired conifer regeneration, but also check soil erosion, serve as deer browse, provide structural diversity, and in the case of alder, serve as a nutrient addition to the site. Because salmonberry development is a concern, and response varies widely by plant association, a comparison of response by association is shown in Fig. 6. Salmonberry cover in the hemlock/blueberry-devil's club association appears to peak between ages 10 and 15, and decline precipitously thereafter. In the hemlock/blueberry associations, it peaks a little earlier but is nowhere near as great.

Consequently it is not a major concern in those associations. Western hemlock-redcedar associations, its cover curve has a flat trajectory, retaining a modest level of cover over time. Interestingly, on hemlock/blueberry/shield fern sites, there is a dramatic increase in salmonberry cover following thinning. A caveat is in order here, however. Data for these thinned sites were collected from a handful of sites on limestone in the Naukati/Tuxekan Island area. Response on soils derived from metamorphic rocks or till may be different. Salmonberry response appears to be more dramatic on limestone. Although a conclusive reason for this has not been shown, it appears to be related to more frequently disturbed soils on these sites, in turn related to subsurface hydrology. Limestone soils are characterized by oxygenated subsurface flow, as well as bedrock with numerous cracks and fissures. This soil environment appears to favor devil's club and salmonberry. Associations characterized by these species appear more frequently on the limestone landscape than on glacial or organic soils.

Response of Deer Browse Species

Maintaining Sitka black-tailed deer habitat remains an important subsistence, sport-hunting, and diversity issue on the Ketchikan Area. Figs. 7-10 illustrate response of understory species considered important deer forage.

The foliage of tall blueberry species (Vaccinium alaskaense and V. ovalifolium) comprises a major portion of deer energy needs (Rose 1989, Hanley et al. 1989). Nutrient (nitrogen, potassium, phosphorus) needs are largely met by the forbs Canada bunchberry (Cornus canadensis), five-leaved bramble (Rubus pedatus), trifoliate foamflower (Tiarella trifoliata), and fernleaf goldthread (Coptis asplenifolia). Fig. 7 shows response of blueberry and forbs for the western hemlock/blueberry association. Blueberry cover tops the old growth level around age 10 and continues to expand, at least until age 20. Canada bunchberry experiences a brief flush of expansion following logging and then declines to less than 5 percent cover at age 20. Other forb levels (bramble, foamflower, and goldthread) remain low throughout.

The western hemlock/blueberry/shield fern association shows a similar response pattern (Fig. 8), although blueberry cover declines by age 20, perhaps reflecting more rapid canopy closure on these sites. Forb response is similar, except that five-leaved bramble cover exceeds old growth levels from about age 5 to age 15 (Fig. 10). Fig. 8 shows increased blueberry cover following thinning in the shield fern association. Forb cover does not appear to be affected by thinning, at least in the period 4-6 yrs following it, remaining miniscule. Fig. 9 summarizes blueberry response among several associations. Data reflects site differences, and thus the rate of seral development. The shield fern association peaks early and then declines, reflecting early canopy closure on the sites where it occurs. Hemlock/blueberry shows a strong response also, but because it is not quite as productive on average as the shield fern type, its response is slightly delayed (ages 0-5) and does not peak until at least age 20. Hemlock/blueberry-devil's club shows a much greater lag, and also has not peaked by age 20. Sitka spruce associations do not appear to reach anywhere near the blueberry levels attained by the hemlock series, but this involves some conjecture, as the picture before age 20 for these stands is not known. Cover for hemlock-redcedar associations both lags behind those of the hemlock series (reflecting less productive sites), and declines more slowly (reflecting the more open canopy associated with these sites)

Deer Browse

Recorded deer browse (of Vaccinium spp.) estimates (Fig. 11) appear low throughout second growth stands. Never exceeding 5 percent regardless of association or time since logging, deer browsing in second growth may be restricted to local concentrations or be delayed until much later. Forage is not the only component of deer habitat, and winter cover may be a more important factor limiting deer populations in southeast Alaska (Wallmo and Schoen 1980). Conserving old growth as winter range, and altering second growth composition and structure to more closely meet deer needs, remain important challenges on the Ketchikan Area.

Slash Accumulation

Slash from logging or thinning operations can be an

impediment to deer movement in and use of second growth stands (Mankowski and Peek 1989). A modest amount of slash data related to deer movement is presented in Figs. 12-14.

Cover of slash less than 30 cm. (1 ft.) deep remains at about 20 percent for stands aged 0-25 in western hemlock/blueberry associations (Fig. 12). Slash in blueberry-devil's club associations is only available for stands aged 10-25, but given the shape of the curve, may show much greater levels initially. It appears to decline significantly at ages 20 and older. Thinning does not appear to have any short-tern effect on 0-30 cm. slash depth, as the value recorded 4-6 yrs following thinning is approximately the same as that recorded in unthinned stands. Slash 0-30 cm. in depth is not considered an impediment to deer movement (Mankowski and Peek 1989). Cover of slash 30-50 cm. (1-1.75 ft.) deep, a moderate impediment to deer movement is low (less than 10%) in hemlock associations (Fig. 13), except for the blueberry/devil's club association, showing about 20 percent cover at ages 10-15. Thinning increases slash for this strata from about 10 to about 15%. Slash at depths of greater than 50 cm. (1.75 ft.) is considered a serious impediment to deer movement. Fig. 14 illustrates slash levels in second growth. In hemlock/blueberry and hemlock/blueberry/shield fern associations, slash cover in this strata is about 25 percent following logging, but by age 15 declines to about 7 percent. Precommercial thinning increases the cover back to about 25 percent, the same level as following logging. Levels for the hemlock/blueberry-devil's club association appear somewhat higher than in the hemlock/blueberry associations (12 percent vs. 7 percent at ages 10-15, for example. Data for the spruce series are incomplete.

Future Data Requirements

Such additional information is needed before a complete assessment of understory response following logging and thinning can be made for the major plant associations of southeast Alaska. Future work should focus on: 1) slash depths and deer browse on a variety of thinned sites at different ages since thinning; 2) vegetation data on thinned sites; 3) estimates of stand density and basal area for the full range of second growth stands, as an aid in developing thinning guidelines; and 4) data on spruce sites younger than age 20, hemlock associations older than 20 years old, and on all stands older than 50 years old. The 1991 Ketchikan Area ecology program field season will focus on the first two items.

Information exists in the ecology data base on tree heights, shrub heights, blueberry stems per acre, available blueberry forage cover, bryophyte (moss) cover, and species richness and equitability. These data will be summarized and reported on at future meetings and in published reports. Coordination of past and ongoing ecological studies in southeast Alaska remains a pressing need. Fine work has been accomplished by researchers at the Juneau Forest Science Lab including Paul Alaback, Bill Farr, and Bob Deal. Data of various types from stands of second growth have been collected by personnel on several Forest Service Districts in southeast Alaska. Collection, analysis, and reporting of this information and other data yet to be collected would be more productive than each group acting separately.

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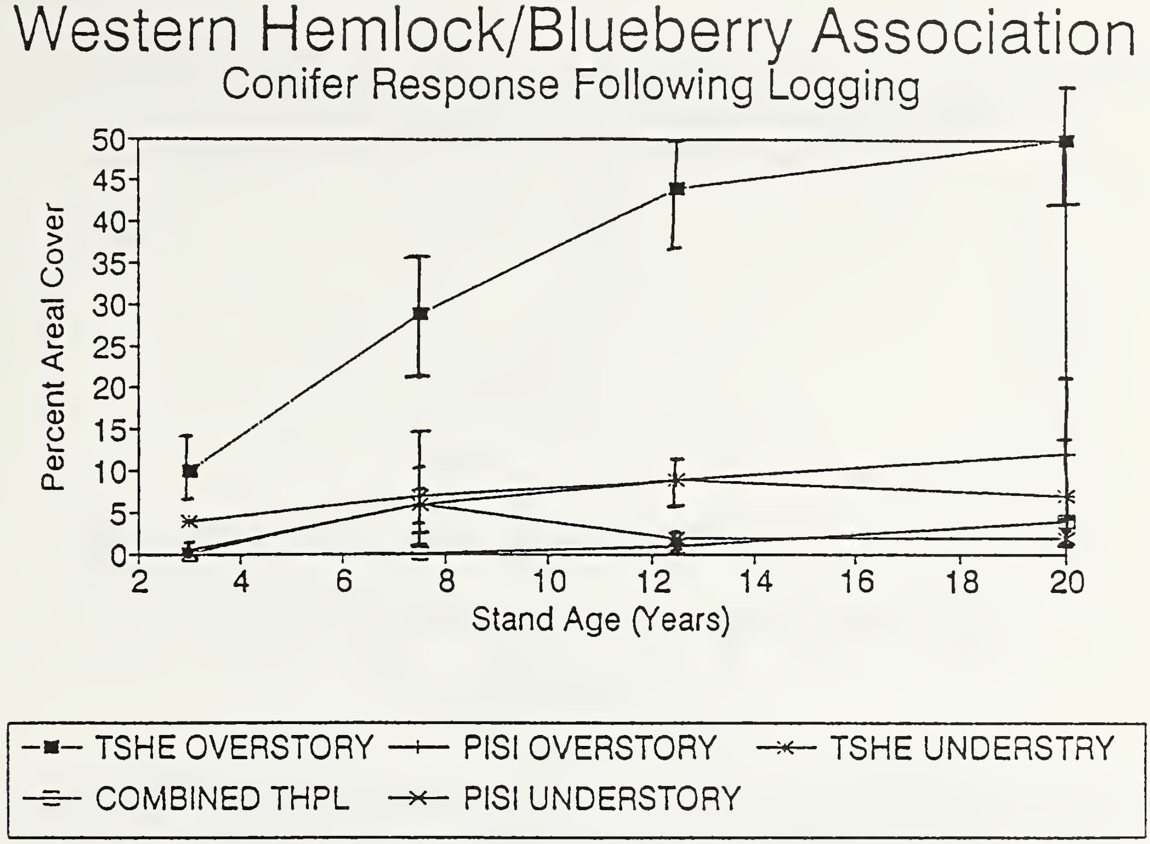

Fig. 1. Western hemlock/blueberry association, conifer response following logging. Intervals represent standard errors of the means.

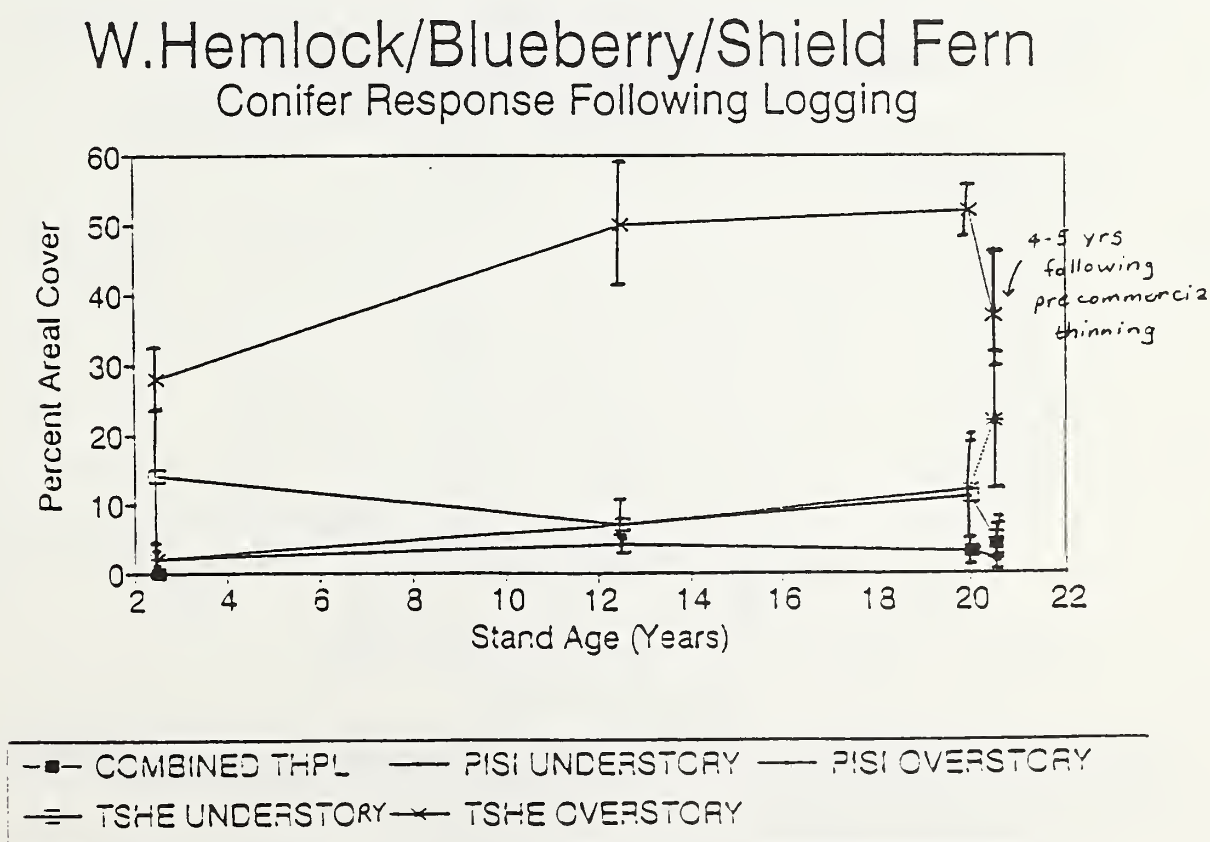

Fig. 2. Western hemlock/blueberry/shield fern association, conifer response following logging. Data at age 20.5 represents effects of precommercial thinning. Intervals represent standard errors of the means.

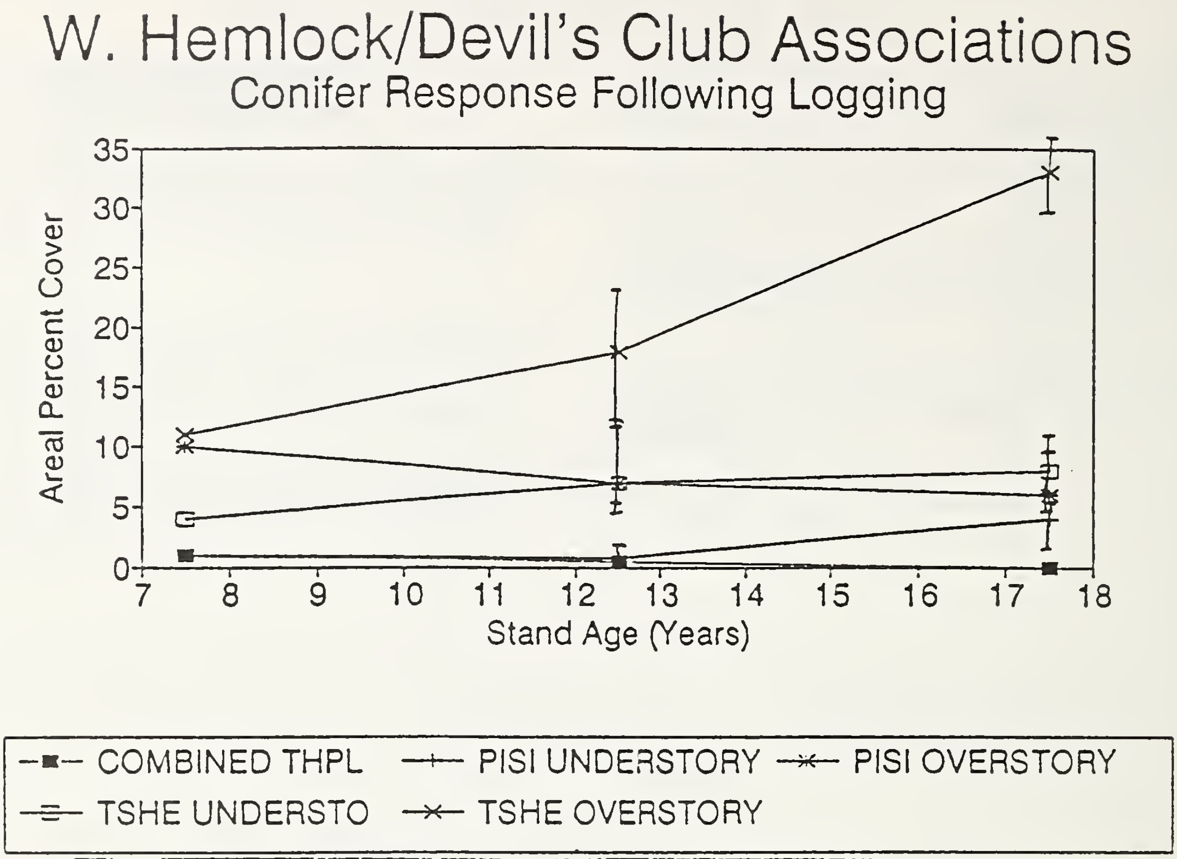

Fig. 3. Western hemlock associations characterized by devil's club, conifer response following logging. Intervals represent standard errors of the means.

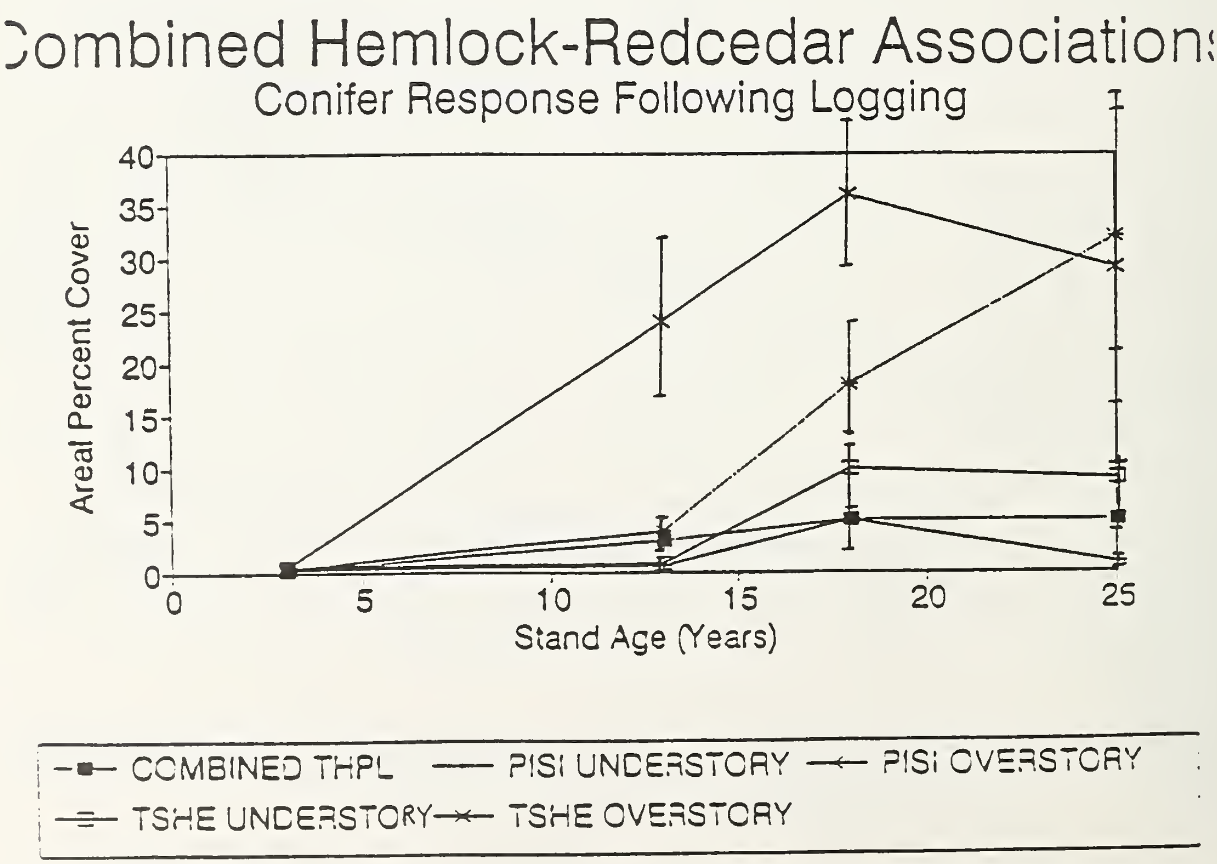

Fig. 4. Combined western hemlock-western redcedar associations, conifer response following logging. Intervals represent standard errors of the means.

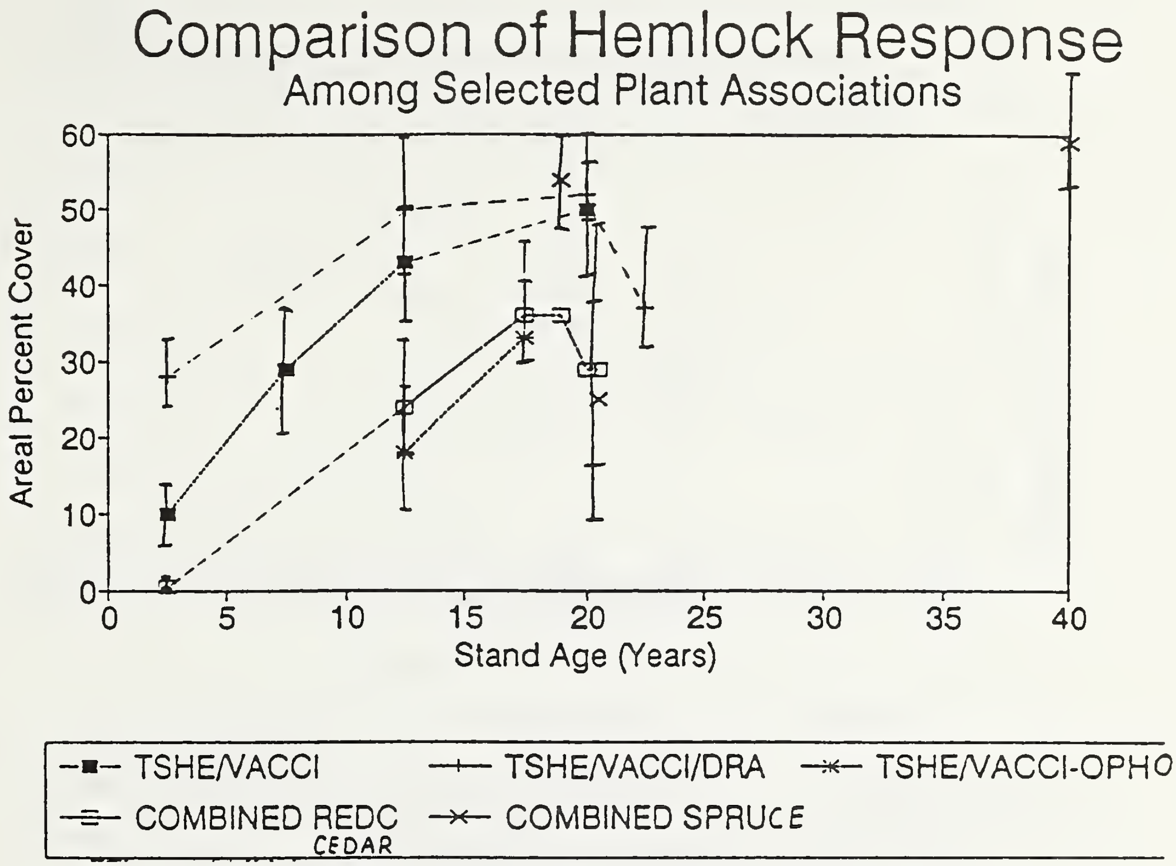

Fig. 5. Comparison of western hemlock response following logging among selected plant associations. Data for shield fern (TSHE/VACCI/DRAU2) and combined spruce associations at ages 20-25 represent precommercially-thinned stands. Intervals represent standard errors of the means.

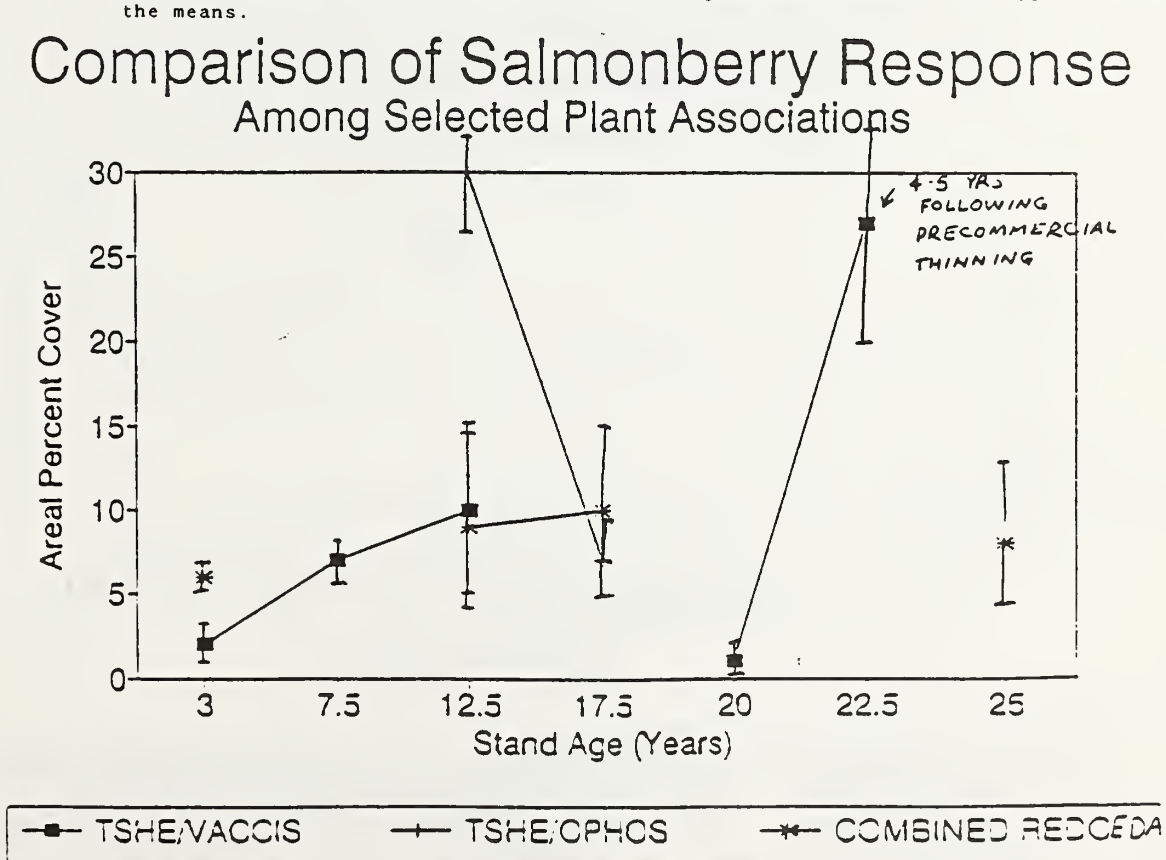

Fig. 6. Comparison of salmonberry response following logging among selected plant associations. Data at age 22.5 represents precommercially-thinned stands. Intervals represent standard errors of the means.

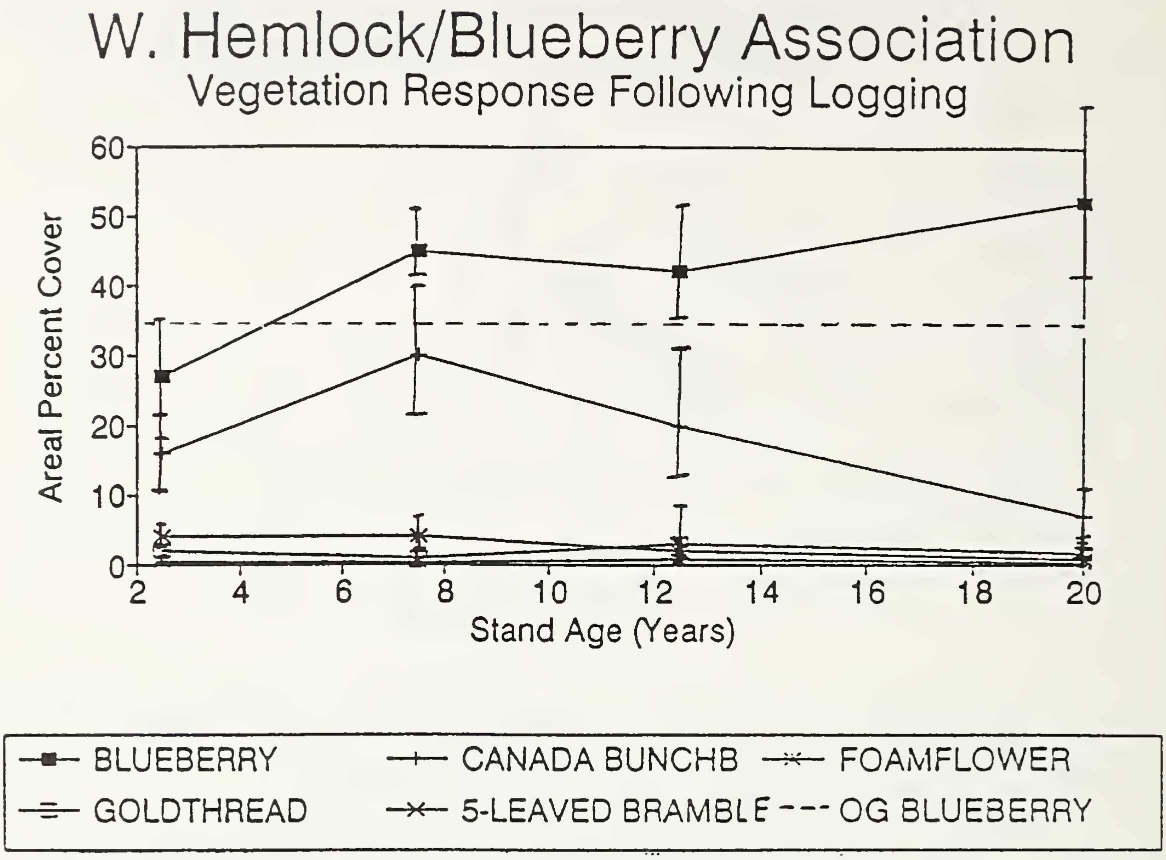

Fig. 7. Western hemlock/blueberry association, vegetation response following logging, species with deer browse value. "OG" designates old growth values for comparison. Intervals represent standard errors of the means.

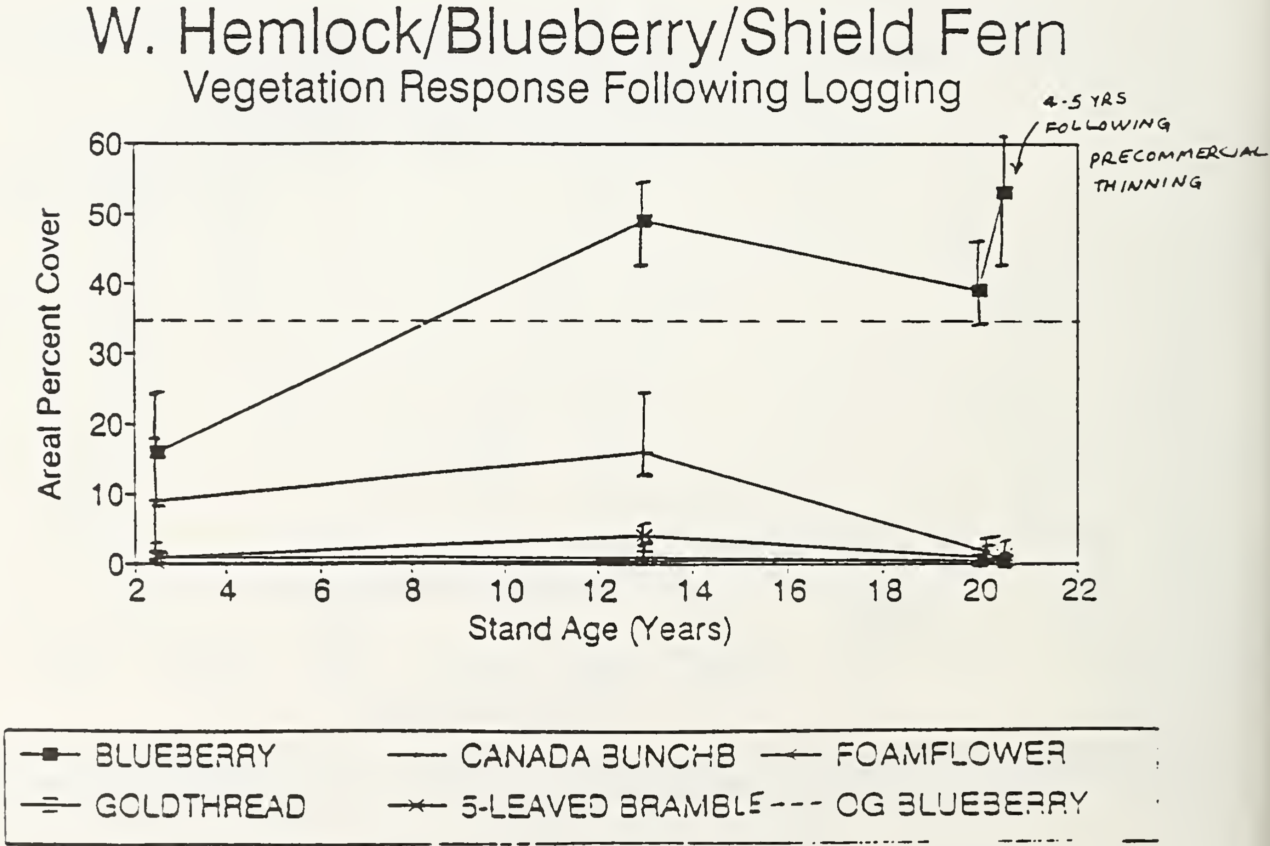

Fig. 8. Western hemlock/blueberry/shield fern association, response following logging, species with deer browse value. "OG" designates mean old growth values for comparison. Data at age 20.5 represent precommercially-thinned stands. Intervals represent standard errors of the means.

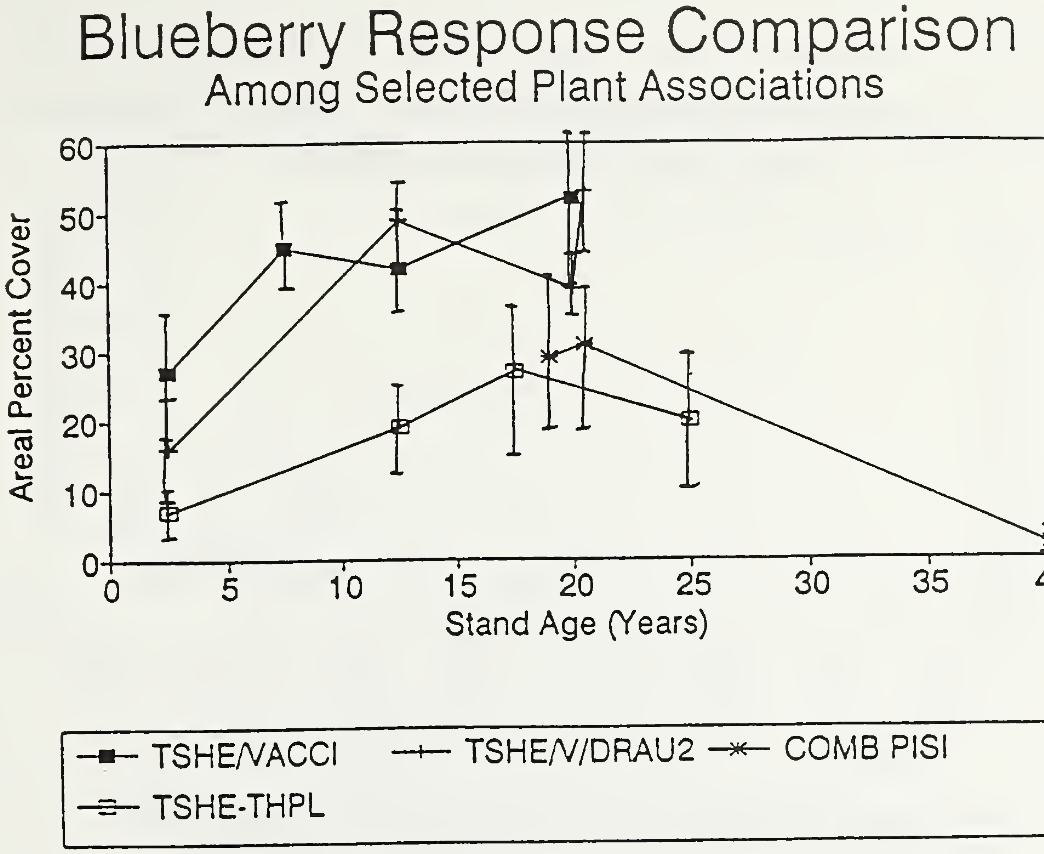

Fig. 9. Blueberry response following logging, comparison among plant associations. Data at age 20.5 for Sitka spruce and shield fern associations represent precommercially-thinned stands. Intervals represent standard errors of the means.

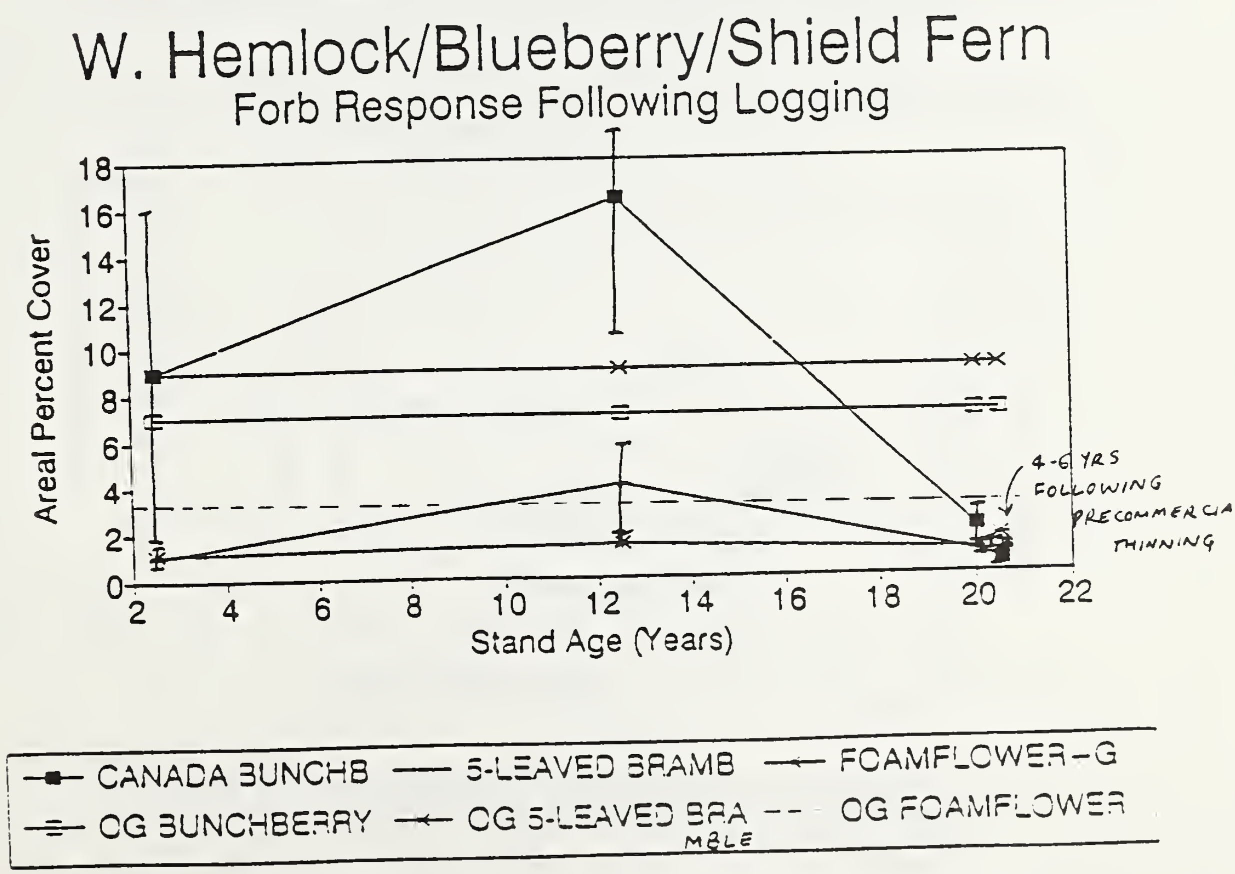

Fig. 10. Western hemlock/blueberry/shield fern association, forb response following logging, compared with stands 4-5 yrs folllowing precommercial thinning (data at age 20.5). Intervals represent standard errors of the means.

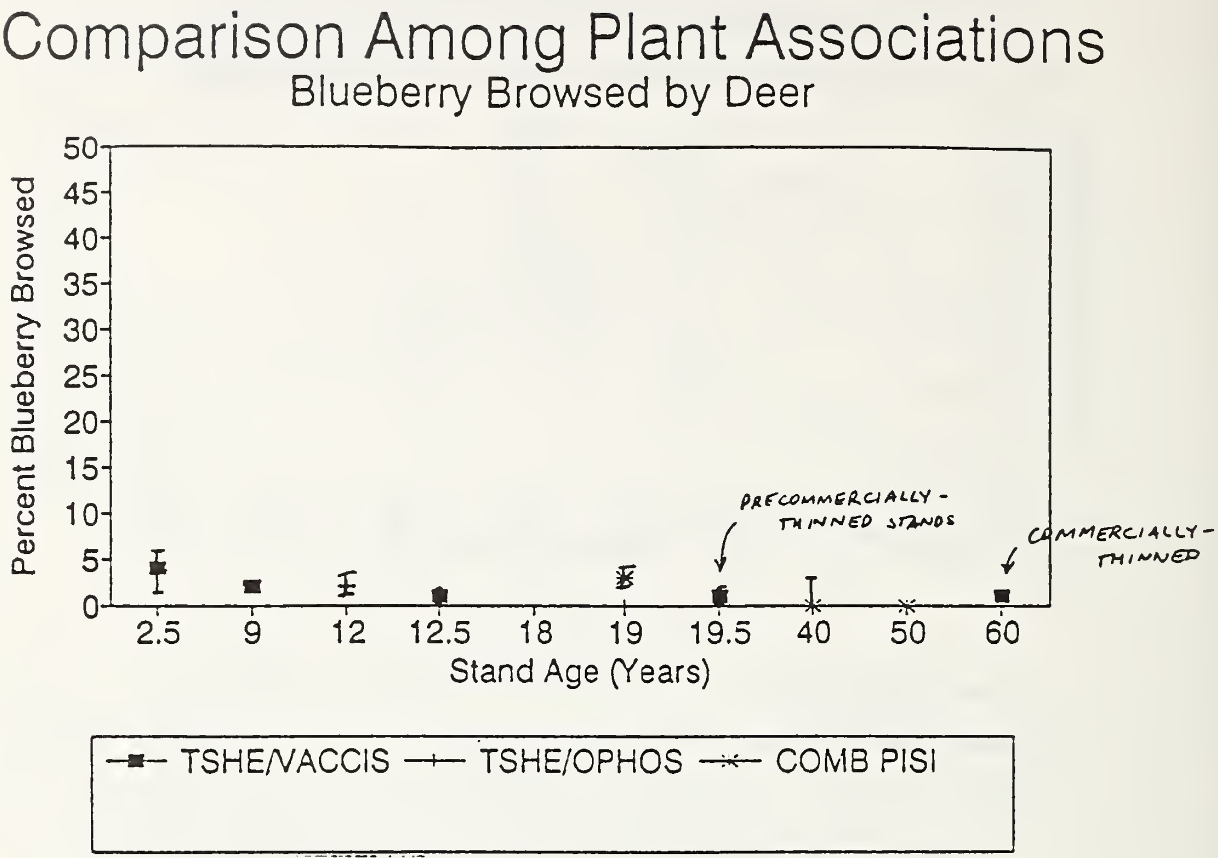

Fig. 11. Blueberry browsed by deer in second-growth stands, comparison among plant associations. Data at age 19.5 represent precommercially-thinned stands. Data at age 60 represent commercially-thinned stands. Intervals represent standard errors of the means.

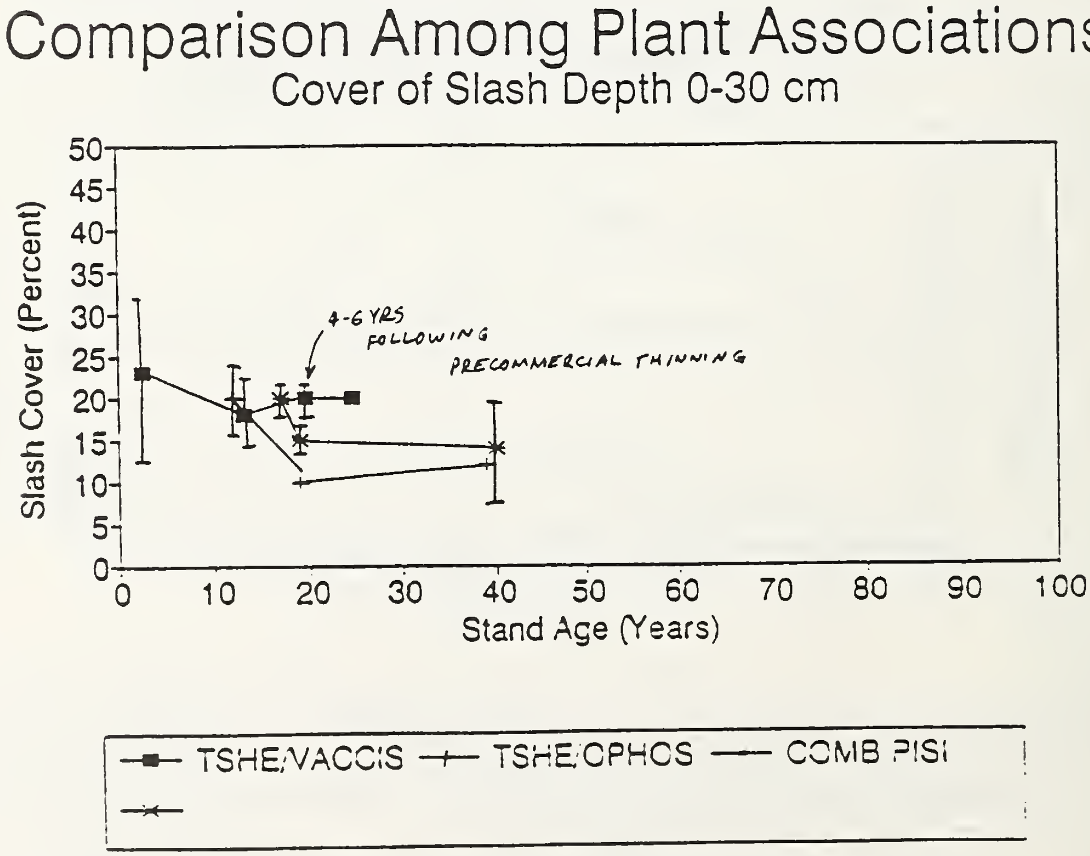

Fig. 12. Slash accumulation as potential deer impediment, cover of slash 0-30 cm above ground, comparison among plant associations. Data at age 19 for hemlock/blueberry associations represent precommercially-thinned stands. Intervals represent standard errors of the means.

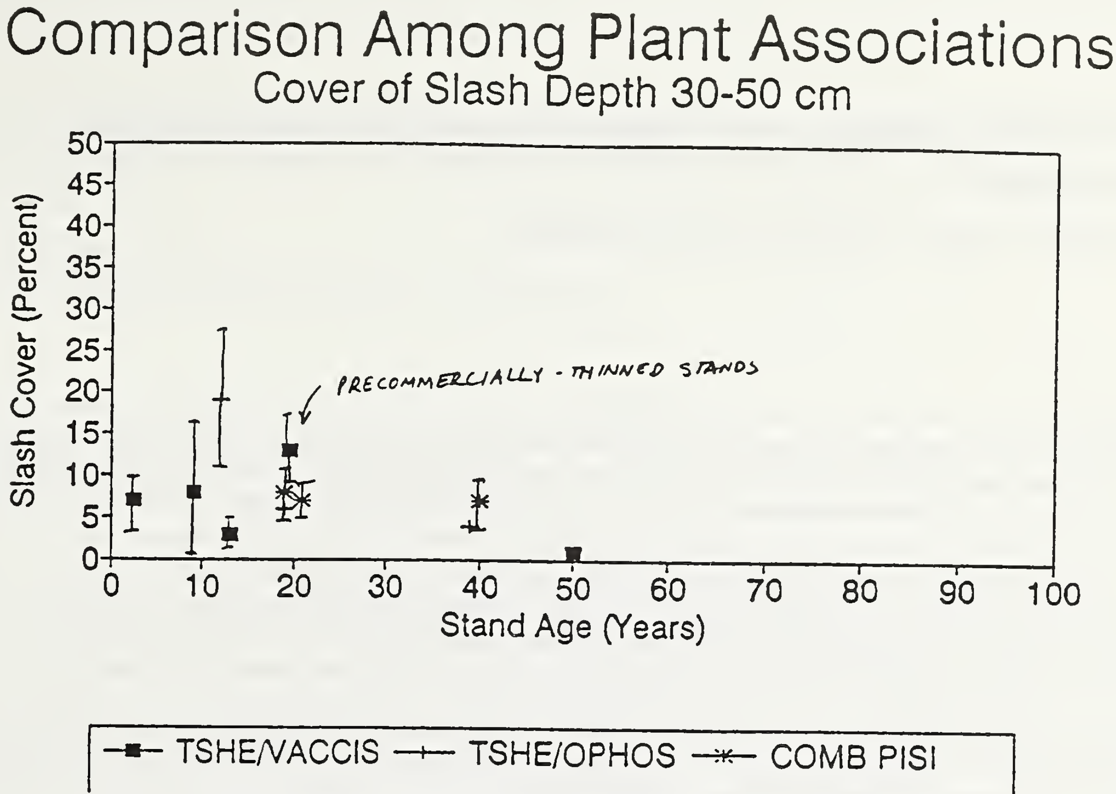

Fig. 13. Slash accumulation as deer impediment, cover of slash 30-50 cm above ground, comparison among plant associations. Data around age 20 for hemlock/blueberry (TSHE/VACCIS) and combined spruce (COMB PISI) stands represent precommercially-thinned stands. Intervals represent standard errors of the means.

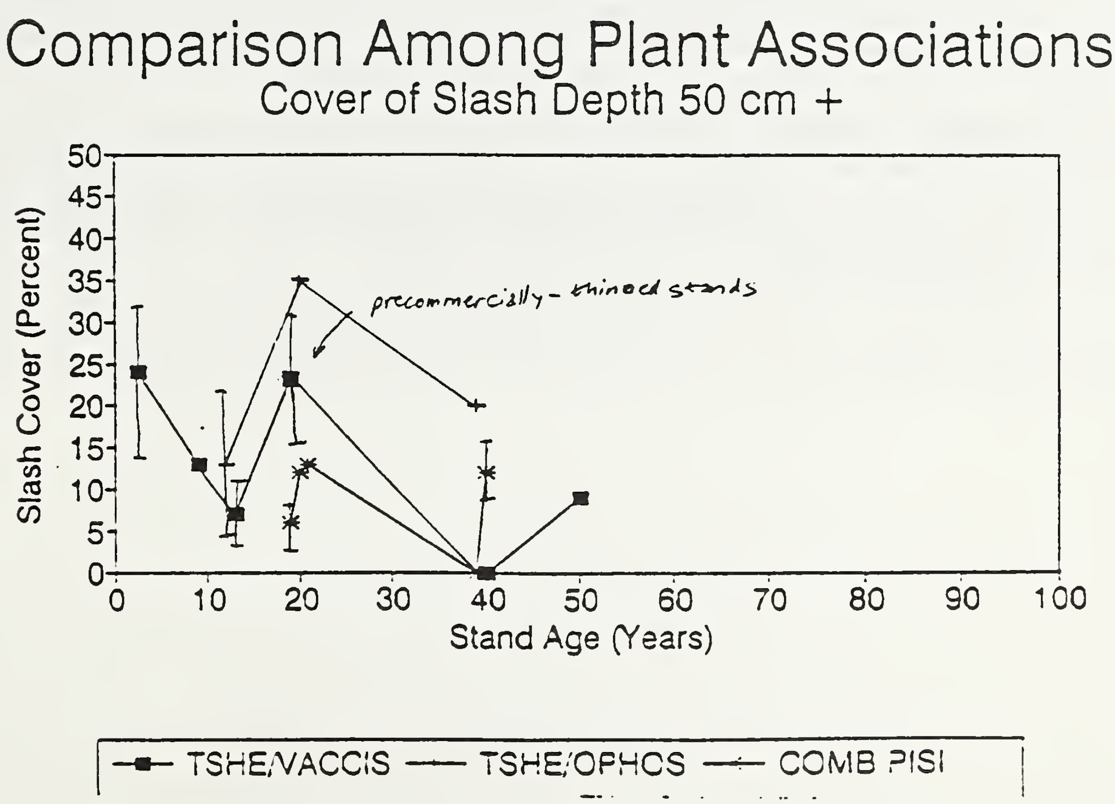

Fig. 14. Slash accumulation as deer impediment, cover of slash 50 cm + above ground, comparison among plant associations. Data around age 20 represent precommercially-thinned stands (except for hemlock/devil's club stands). Intervals represent standard errors of the means.

An Intergrated Inventory of the Copper River Delta, East and West Halves

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ABSTRACT: An Integrated inventory of the Copper River Delta was initiated in 1984 and completed in 1990. The major objective of the inventory was to map the landforms, soils, and vegetation in order to determine the physical relationship between these components and to create a data base from which the Forest could manage wildlife habitat and other activities. A secondary objective was to create a Geographic Information System (GIS) data base which could be used to monitor changes in the landform, soils, and vegetation. A field team consisting of a soil scientist and a botanist or wildlife ecologist (biologist) with plant taxonomy knowledge was selected to insure the data collected was truly integrated and not skewed toward a particular discipline. Landforms, which are essentially synonymous with soils, were used as a mapping base to tie vegetation to a feature that was relatively stable. Plant species and cover percentages were determined, using the Daubenmire method; and representative soil profile descriptions were collected from 208 transects across premapped landforms. The vegetation analyses were grouped together using similar plant species with similar percent covers through the cluster analysis program Twinspan. These analyses were interpreted two ways; the first considered the community associations separated by the clustering. The second interpretation separated the landforms within the clusters and examined the community association on each landform.

The results from the cluster analyses illustrated how a plant community may be representative of one successional stage on one landform and another successional stage in another landform. The analyses also indicated that at this level of inventory more than one plant community or successional stage may occur on the same landform. Hence, a more intensive inventory must be completed to identify the specific plant communities and successional stages on each landform. The primary division of vegetation samples were the groups that contained Carex lynbyaei or other sedges and grasses, and the groups with a true overstory of woody vegetation.

Tables were developed that list the physical properties of the soils and landforms, and interpreted the potential for management activities. Interpretations were made for the development of ponds, recreational cabins, foot trails, and the potential for the soil to be used as a source of sand, gravel, or road fill. Other tables estimate the occurrence of potential feeding habitats for moose, dusky Canada goose, and trumpeter swans; and identify which map units qualify as jurisdictional wetlands.

Sustaining Watershed Values While Developing Taiga Forest Resources

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ABSTRACT: The "traditional" values of forested watersheds include maintenance or enhancement of stream quality, of total quantity of water yielded, and of timing of that yield. In subarctic central Alaska these values must be addressed in a context of possible major climate alterations, and of possibly increasing timber production from taiga forests.

The taiga -- the high-latitude forest of the discontinuous-permafrost zone of central Alaska -- is particularly susceptible to modification under present scenarios of global climate change. Increase of mean annual temperature by as much as 6°C has been postulated; since the ground temperature of permafrost in central Alaska is -1/2 to -4°C, there is clearly the possibility of warming and thawing of a major proportion of the central Alaska landscape.

Such warming would have many implications for maintenance of watershed values: thaw-unstable slopes, increased sedimentation into headwaters streams, altered biological productivity of streams, shifts of the seasonality and total area of wetlands, changing species composition and productivity of forest stands, and altered responses of upland watersheds to resource management practices are among the possibilities.

The extensive forests of central Alaska's taiga are presently only modestly utilized for commercial timber. The annual timber harvest for central Alaska (between the Alaska Range and the Brooks Range) is ca. 12-15 MM board feet. The forest resources of the taiga may be subjected to increasing pressures for wood products. Factors arguing for increased utilization include State and regional actions toward developing a Pacific Rim market for Alaskan forest products; a gradually increasing local population which now relies primarily on lumber imported from Canada, Oregon and Washington, but which could shift toward greater dependance on locally produced lumber; and possible increased export of wood products from central Alaska in response to changing forest management policies in Southeast Alaska and the Pacific Northwest.

Assuring long-term sustained maintenance of watershed values, concomitant with increased production of forest products including timber, will require improved understanding of present taiga ecosystem status and function, and better understanding of the cumulative consequences of resource management practices at the catchment and regional landscape scale. Developing this improved understanding will require extension of current catchment-oriented taiga watershed research to a regional, landscape level. That action will, in turn, require commitment by management and research entities to sustained, long-term support of research and monitoring in taiga watershed systems.

Monitoring Ecosystems, Northern Linkages: USDA Forest Service Global Change Research

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ABSTRACT: Foresters and natural resource managers have traditionally based long-term plans (i.e. 100+ year harvest cycles) on the assumption of stable landscapes and climate. Global climate change undercuts these assumptions and may alter or invalidate some accepted natural resource management practices and paradigms. Possible changes in biomass productivity, shifting of forest species latitudinal or elevational limits, and rapid changes in forest community species and age class composition, all have major implications for management of the nation's forests.

The USDA Forest Service is undertaking a national research program to assess rates, significant processes, and management implications of possible climatic change for the nation's forests and related resources. Pacific Region Forest Service global change research places major emphasis on understanding and monitoring forest processes in the northern boreal forest and the subarctic taiga of Alaska, which is potentially "sensitive" to climatic warming and to shifts in precipitation regime.

A major terrestrial carbon pool, taiga forests and organic soils may also be important in the flux of greenhouse gases between landscape and atmosphere.

Forest Service research emphasizes an ecosystem approach, incorporating landscape and watershed-level field research with smaller-scale studies of forest ecosystem response mechanisms. Ecological monitoring is critical, and includes establishment of a monitoring mega-transect from northern latitudinal treeline to mediterranean/dry temperate forest/shrublands. Emphasis is placed on the most critical Pacific Region ecosystems: northern boreal forest (taiga), moist temperate forest, and mediterranean/dry temperate forest (chaparral/southern Ponderosa pine).

Maintaining long-term stability of upland landscapes and watersheds, and utilization of complete watershed systems as facilities for research and monitoring in global change research, are major features of this Forest Service research initiative.